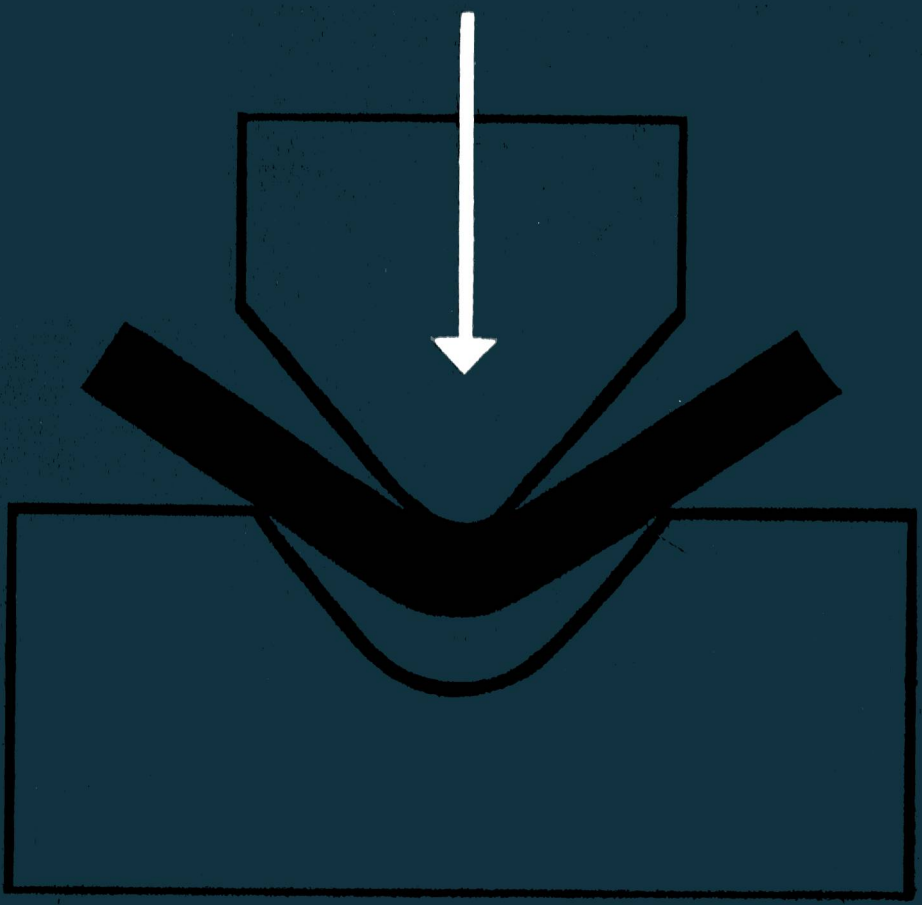
PRESSWORKING

S. A. Elenev



С. А. Еленев

ХОЛОДНАЯ ШТАМПОВКА

МОСКВА «ВЫСШАЯ ШКОЛА»

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PRESSWORKING

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The Russian Alphabet and Transliteration

А а	a	К к	k	Х х	kh
Б б	b	Л л	l	Ц ц	ts
В в	v	М м	m	Ч ч	ch
Г г	g	Н н	n	Ш ш	sh
Д д	d	О о	o	Щ щ	shch
Е е	e	П п	p	Ъ	″
Ё ё	e	Р р	r	Ы	y
Ж ж	zh	С с	s	Ь	′
З з	z	Т т	t	Э э	e
И и	i	У у	u	Ю ю	yu
Й й	y	Ф ф	f	Я я	ya

This textbook in intended for vocational training of pressworking equipment operators and, in particular, for preparing pressmen of class 3. It is written in compliance with the syllabus adopted for vocational schools.

The textbook contains data on the pressworking equipment, design, operation and repair of press tools, outlines basic operations carried out on presses, discusses the problems involved in inspection of stampings, standardization and product quality, mechanization and automation of pressworking and in safety precautions.

На английском языке

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Chapter I

INTRODUCTION TO PRESSWORKING

Pressworking is a mechanical working of metals in which the latter are subjected to plastic deformation in a cold state. Pressworking is divided into sheet stamping and cold die forging depending on the material used and the workpiece to be manufactured.

Stamping is used for making sheet material items such as automobile parts (roofs, fenders, caps, etc.), components of aircraft, railway cars, chemical apparatuses, electrical appliances and a variety of consumer goods (cans, spoons, pots, etc.).

Cold die forging is used for making parts from blanks, substantially from bar stock. Such parts include fasteners (bolts, nuts, rivets), balls, rollers, races of bearings, a plurality of automobile parts (e.g., piston pins), components of aircraft, tractors and the like.

Cold die forging offers a number of advantages over hot forging: it does not include the step of heating the metal, the metal surface layer is not oxidized (hence no scale is formed), the articles have more accurate dimensions and higher surface finish.

If compared with cutting, cold die forging decreases consumption of metal, since no chips are produced, reduces labour input, and increases productivity. At the same time cold mechanical working strengthens the metal, which provides for manufacturing parts of lesser weight and higher wear resistance.

These advantages ensure replacement of castings with pressed pieces. Additional advantages of pressworking, as compared with casting, reside in that stampings and cold die forgings minimize the need for subsequent machining, while castings should be subject to considerable cutting.

In the course of pressworking, blanks, workpieces and parts are obtained as a result of plastic deformation or division of the source material in special tools referred to as "press tools". The press tools are mounted on presses.

The principal operations of sheet stamping include: cutting operations (shearing, blanking, piercing, etc.) and forming operations (bending, drawing, flanging, beading, straightening, etc.). The principal operations of cold die forging are cutting (shearing, piercing) and forming (upsetting, heading, extrusion, coining, sizing and some others). Besides, pressworking is used for assembling workpieces. These operations are discussed at greater length in Chapters V and VI.

Sheet stamping and cold die forging are carried out mainly on hydraulic and mechanical (mostly crank) presses. In addition to

presses, use is made of machines for spinning, high-energy forming, etc. The pressworking equipment is described in Chapter IX.

The sheet stamping materials include sheets or strips, whereas in cold die forging bars of various cross sections are substantially employed. The pressworking materials arriving at the press-shop may be subject to special treatment, such as straightening, annealing, degreasing, pickling, washing, drying and skin rolling. The materials used for pressworking and methods of their preparation are discussed in Chapters III, VIII.

The manufacture of pressed articles comprises a number of operations (e.g. cutting, blanking, drawing, trimming). The sequence of

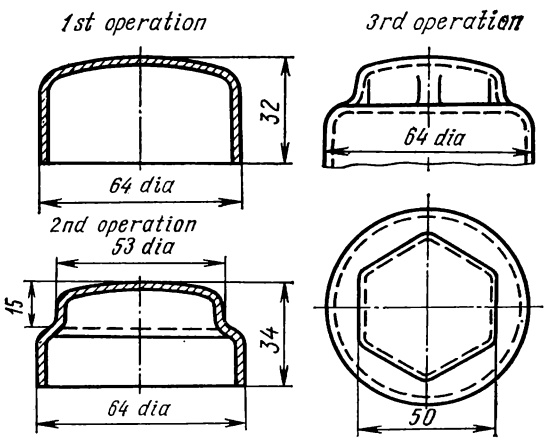


Fig. 1. Forming operations in stamping of an automobile front wheel hub cap

such operations is determined by the manufacturing process which is elaborated by the process engineer of the shop or factory.

The manufacturing process may include special operations for preparing the material for pressworking, pressworking operations (cutting, forming, assembling), quality control operations and finishing operations.

The quality control operations may include intermediate operations for controlling the quality of a workpiece after each step and final quality control operations for checking the quality of the finished article.

The finishing operations comprise trimming, polishing, and applying decorative and protective coatings.

Examples of manufacturing cold stamped and die forged parts are given below.

To stamp an automobile wheel hub cap, a sheet of steel 08, 2.5 mm thick, is cut into strips. The process comprises three operations. The

first operation includes blanking of a piece, 100 mm in diameter, and drawing (Fig. 1). The second operation is essentially a preliminary forming and the third is a final forming which includes making a hexahedron for the wrench. After facing and threading the cap is sent to the assembly line.

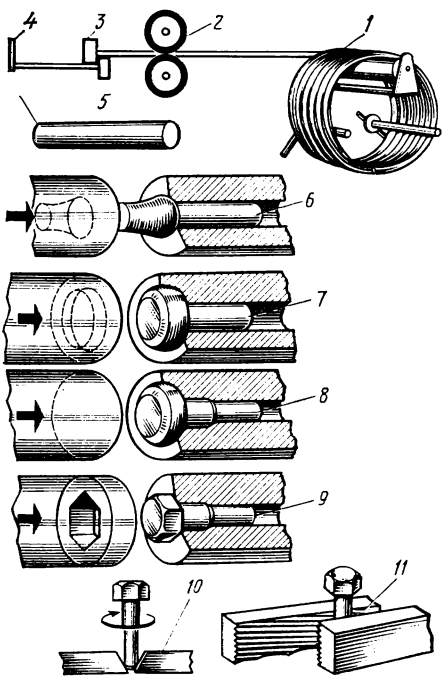


Fig. 2. Manufacture of a bolt on a multi-station automatic heading and threading machine

Figure 2 illustrates operations required for manufacture of a bolt on a multi-station automatic heading and threading machine. The source material is cold-drawn metal bar *1*. Rollers *2* feed the metal bar to thrust against stop *4*. Cutter *3* cuts blank *5* and transfers it to first station *6* where the metal is set for heading. The transfer device automatically moves the blank from one station to another. At second station *7* a cylindrical head is formed. At third station *8* the rod diameter is reduced for rolling the thread. At fourth station *9* the bolt head is cut to make a hexahedron for the wrench.

The modern multi-station automatic heading machines are provided with devices *10* and *11* for chamfering the stem end and rolling the thread.

The pressworking technology is developing towards raising the level of pressworking equipment automation, creating new program-controlled machines and lines.

Review Questions

1. Name the parts obtained by pressworking.
2. What are the advantages of pressworking over other methods of machining?
3. What are the source materials for sheet stamping and cold die forging?

Chapter II

FUNDAMENTALS OF MECHANICS OF MATERIALS

1. Definition of Deformations and Stresses

Deformation is the alteration of the form or shape of a body under the action of forces applied to it. Deformation may be elastic or plastic. If the body resumes its original shape after the force has been removed, the deformation is termed "elastic", if the original shape is not regained, the deformation is "permanent" or "plastic".

The elasticity and plasticity are inherent to some extent in all solids. When being acted upon by external forces, the solids counteract the strain and forces tending to return the solid atoms to the original positions develop inside the solids. These forces are called "internal" and their intensity is estimated by a stress.

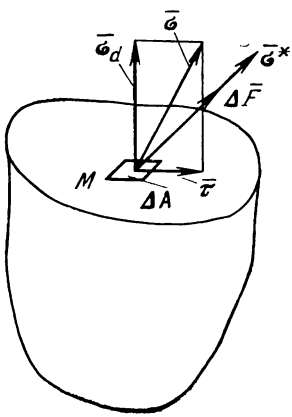


Fig. 3. Direct and shearing stresses

Stress $\bar{\sigma}^*$ across an element of area ΔA inside a solid is the ratio of force $\Delta\bar{F}$ acting on the element to ΔA (Fig. 3):

$$\bar{\sigma}^* = \Delta\bar{F}/\Delta A \tag{1}$$

The limit of this ratio for $\Delta A \to 0$ is a true stress at point M to which the element being considered is contracted:

$$\bar{\sigma} = \lim_{\Delta A \to 0} \frac{\Delta\bar{F}}{\Delta A} \tag{2}$$

Stresses are measured in MN/m^2 (formerly used dimensions of kgf/cm^2 or kgf/mm^2 can be also found in the literature). Stress vector $\bar{\sigma}$ can be resolved into components $\bar{\sigma}_d$ and $\bar{\tau}$. Direct stress $\bar{\sigma}_d$ is normal to the element; shearing stress $\bar{\tau}$ is tangential on the element surface (Fig. 3).

2. Simple Deformations

A solid undergoes tension (compression) under the action of normal forces (Fig. 4*a*, *b*) distributed uniformly over the base areas. When a bar with original length l_0 is subject to tension, its length after deformation will increase by Δl (or decrease by Δl in the case of compression). The value Δl is termed total or absolute elongation in tension (or total shortening in compression). The ratio of Δl to the

original length of a specimen is known as elongation (compression):

$$\varepsilon = \Delta l / l_0$$

A solid which is subject to only tangential stresses τ undergoes shearing strain (Fig. 4*c*). The parallelepiped edges do not change their length. The measure of deformation in this case is the angle γ by which the original normal angle of the parallelepiped face has changed.

Twisting (Fig. 4*d*) is found in a bar which is acted upon by a couple of forces lying in the planes normal to the bar axis. A torsion angle is the measure of deformation in this case.

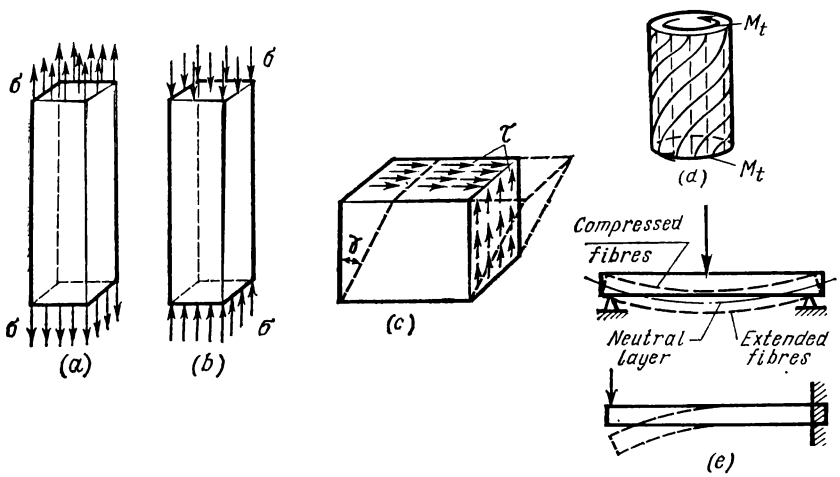


Fig. 4. Principal types of deformations
(*a*) tension; (*b*) compression; (*c*) shearing; (*d*) twisting; (*e*) bending

In bending (Fig. 4*e*) the straight axis of the bar gets curved. The fibres on the concave side compress while those on the convex side, elongate. The layers which do not undergo tension or compression are defined as neutral. The curvature of the bent axis of the specimen characterizes the amount of bending strain.

3. Hooke's Law

Strain in most of elastic solids is proportional to the magnitude of forces acting upon them. This property of elastic solids was discovered by the English scientist Robert Hooke in 1660. Hooke found out that elongation of a spring under a tensile force is directly pro-

portional to this force and worded his discovery as follows "the extension is proportional to the force producing it".

Materials undergo elastic deformation according to Hooke's law. When a bar is subject to tension or compression the change of its length is proportional to the tensile or compression force; at twisting, the torsion angle is proportional to torque M_t; if a beam is bent, its deflection is proportional to the load.

The general rule stating that the deformation is proportional to the force producing it is known as Hooke's law to commemorate the scientist who was the first to discover it. The to-day s formulation of this law considers the relationship between strains and stresses.

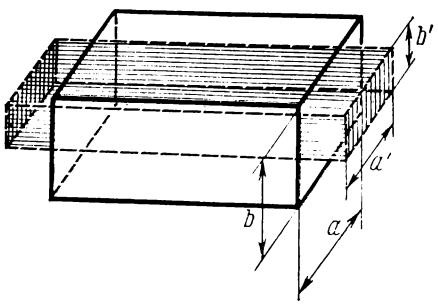


Fig. 5. Determination of lateral strain in tension

At tension or compression

$$\sigma = E\varepsilon \qquad (3)$$

where the constant E is termed the modulus of elongation or Young's modulus of elasticity. As seen from formula (3), Young's modulus E has a numerical value of stress σ since per cent elongation ε is not dimensional. Young's modulus characterizes the ability of a material to resist deformation. The quantity E is determined experimentally. For instance, steel has $E = (2.0\text{-}2.2) \times 10^5$ MPa or $(2.0\text{-}2.2) \times 10^4$ kgf/mm^2, and copper, $E = 1 \times 10^5$ MPa or 1×10^4 kgf/mm^2.

When substituting $\sigma = F/A$ (F is tensile or compression force, A is the bar cross section area) and $\varepsilon = \Delta l/l$ in formula (3), we obtain

$$\Delta l = Fl/EA \qquad (4)$$

As transpires from the formula, the elongation (compression) of a rod is directly proportional to the tensile (compression) force and to the rod length and is inversely proportional to Young's modulus and the cross section area. Product EA is termed rigidity in tension (compression).

Elongation of the bar in the longitudinal direction results in its lateral contraction. Longitudinal strain ε relates to lateral strain $\varepsilon' = (a' - a)/a = (b' - b)/b$ (Fig. 5) as follows:

$$\varepsilon' = -\mu\varepsilon \qquad (5)$$

The values ε' are negative at tension and positive at compression (the bar expands). The non-dimensional value μ is known as a

contraction coefficient or Poisson's ratio. The value of μ varies from 0 to 0.5 depending on the materials. When performing calculations for steel, $\mu = 0.3$ is assumed.

At shearing, Hooke's law is written as follows:

$$\tau = G\gamma \tag{6}$$

The constant G is known as the modulus of rigidity and has the dimension of stress. G may be defined by E and μ:

$$G = \frac{E}{2(1+\mu)} \tag{7}$$

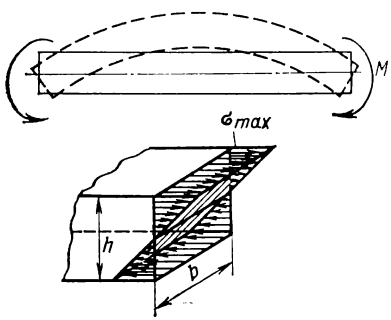


Fig. 6. Pure bend stresses

Formula (6) is structurally similar to formula (3) which defines Hooke's law for tension.

In torsion of a circular shaft, assuming that only tangential stresses develop in the lateral cross sections and the latter turn as flat disks, the total torsion angle is determined from the formula

$$\varphi = M_t l/GI_p \tag{8}$$

where l is the bar length, M_t is the torque, I_p is the polar moment of inertia (for a circle, dia. d, $I_p = \pi d^4/32$).

Shearing stresses τ at cross section points remoted from the bar axis through distance ρ are found

$$\tau = M_t \rho / I_p \tag{9}$$

The maximum shearing stress at torsion may be found from formula (9) assuming $\rho = r$ (r is the bar radius):

$$\tau_{max} = M_t/W_p \tag{10}$$

The value W_p is termed the polar moment of resistance; in the case of a solid circular shaft $W_p = I_p/r = \pi d^3/16$.

In bending (Fig. 4*e*), shearing force Q and bending moment M act in the specimen cross sections normal to its axis. If the internal forces in the lateral cross sections of the specimen are referred to only bending moment M and $Q = 0$, the bending is known as pure. In pure bending only direct stresses σ_z occur in the cross section (axis z is aligned with the axis of the specimen).

These stresses reach their maximum at points which are most distant from the neutral axis (Fig. 6). The values of σ_{max} in the section being considered are determined from the formula based on Hooke's law:

$$\sigma_{max} = M/W \tag{11}$$

where W is the moment of section resistance to bending. The values of W for different section profiles are given in reference books. For instance, in the case of a rectangular section with base b and height h

$$W = bh^2/6$$

and for a circle, dia. d,

$$W = \pi d^3/32$$

The section of maximum stresses is termed ultimate.

Stresses near the neutral surface are insignificant and the adjacent layers of metal do not work almost. Therefore, to decrease the weight of the structure, use is made of tubular parts, flange beams, etc.

4. Stress-Strain Relationships

The direct relationship between stresses and strains (Hooke's law) holds good only up to certain limits which differ with materials. Such limits as well as mechanical properties of materials are determined by special tests, the tensile test being the most popular.

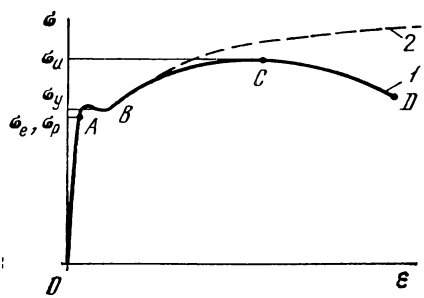


Fig. 7. Steel specimen tension curves
1 — calculated curve; *2* — true curve

A prismatic or cylindrical specimen with a length of l_0 and cross section area A_0 is subjected to tension; tensile force F and specimen length l are measured in the course of test. These data are used for calculating equivalent stress $\sigma = F/A_0$ and per cent elongation $\varepsilon = (l - l_0)/l_0 = \Delta l/l_0$ the values of which are plotted in a particular scale on the ordinate and abscissa respectively.

Figure 7 shows relationship between σ and ε for mild steel. The direct proportionality between σ and ε is maintained, i.e. Hooke's law holds good, up to point A. The maximum stress to which the strains rise in direct proportion to the stresses is known as the limit of proportionality and is defined by σ_p.

To determine limit of elasticity σ_e, the specimen is relieved after each application of load and its length is measured to find out the appearance of plastic deformation. The stress at which a plastic deformation of about (0.000 02-0.000 05) l_0 appears is known as a limit of elasticity. For mild steel $\sigma_p \approx \sigma_e$.

With a further increase of the tensile force, a moment arrives when elongation of the specimen occurs without any noticeable increase of stress (the horizontal flat of the curve). The stress at

which such a flow of metal takes place is called the yield point and is defined by σ_y. The yield point is a very important characteristic of mechanical properties of a material. By comparing the calculated stresses with the yield point, it is possible to estimate the nature of deformation in the material.

For materials the tensile curve of which does not have a pronounced yield elongation zone, the stress corresponding to the permanent per cent elongation of 0.2% is assumed to be the yield point.

After point B of the curve (Fig. 7) the material regains its ability to resist plastic deformation at an increase of the load. Such a phenomenon is known as strengthening. Over the strengthening section the relationship between stresses and strains no longer obeys Hooke's law. The tensile force reaches its maximum, F_{max}, at point C. The quotient of dividing F_{max} by the original cross section area A_0 of the specimen is called the ultimate strength $\sigma_u = F_{max}/A_0$. The specimen elongates uniformly up to the point C and after the ultimate strength is reached, a local contraction, or a neck, is formed. The bulk of the specimen is not deformed. The section at the middle of the neck decreases rapidly and further elongation of the specimen up to the rupture (point D) occurs with a decrease of the load.

Note that the effective stresses in the specimen keep on growing after point C despite the decrease in force F, since the area of the neck cross section diminishes continuously. The ratio of the force corresponding to point D to the neck cross section area at the moment of rupture exceeds the ultimate strength.

Ultimate strength σ_u is determined experimentally and is one of the principal characteristics of a material.

Plastic properties of a material may be estimated by the values of per cent elongation ε (the abscissa of point D on the curve) and per cent contraction ψ after the rupture of the specimen. These values are found from the following equations:

$$\varepsilon = \frac{l_f - l_0}{l_0} \times 100\%, \quad \psi = \frac{A_0 - A_f}{A_0} \times 100\%$$

where l_f and A_f are the final length of the specimen and the neck cross section area after the rupture, respectively, while l_0 and A_0 are the original values of the specimen length and cross section area.

If the force is referred to the actual cross section area of the specimen, rather than to the original one, we obtain the true tensile curve which is shown in Fig. 7 by a dash line.

5. Strength Analysis

In engineering calculations the strength of a bar working in tension or compression is estimated by the stress which develops in it at loading $\sigma_u = F/A$.

This stress is compared with the permissible one, $[\sigma]$, selected depending on the material and working conditions of a given structure. For plastic materials, $[\sigma] = \sigma_y/n_y$, for brittle ones, $[\sigma] = \sigma_u/n_u$.

The safety factor with respect to yield point n_y or ultimate strength n_u is assigned to compensate for possible overloads in operation, inaccurate manufacture of parts and to determine mechanical properties of the material. The values n_y and n_u always exceed one. Brittle materials (cast iron, concrete, etc.) destroy without noticeable permanent deformations, therefore the ultimate strength is the basic characteristic for their mechanical properties.

Establishment of the safety margins is a vital economic problem. Decreasing the safety factor saves materials; on the other hand, normal operation of the articles should be guaranteed for a definite period of time.

There are no universal norms for permissible stress limits in the machine building industry. However, vast production experience gained at some big plants and separate branches has made it possible to establish permissible stress limits compulsory for these plants.

Strength analysis in tension (compression), with the value of $[\sigma]$ selected, is reduced to obeying the inequality

$$F/A = \sigma \leqslant [\sigma]$$

This inequality provides for determining the cross section area $A \geqslant F/[\sigma]$ by the assigned values of force F and permissible stresses $[\sigma]$ or the permissible load by the known values of $[\sigma]$ and A:

$$F \leqslant [\sigma] \cdot A$$

The shearing strength formula has the following form:

$$\tau = F/A \leqslant [\tau]$$

The permissible shearing stresses $[\tau]$ are usually selected to be $[\tau] \approx \approx 0.8\,[\sigma]$.

The torsion strength is found from the following formula

$$\tau_{max} = M_t/W_p \leqslant [\tau]$$

Besides, the need for limiting the angle of torsion may arise on some occasions. In such a case, the permissible value of angle φ is found and compared with the angle of torsion obtained from the formula (8).

The bending strength equation relates the maximum direct to permissible stresses:

$$\sigma_{max} = M/W \leqslant [\sigma]$$

6. Stress at a Point

If an elementary parallelepiped is defined at an arbitrary point of the solid being deformed, direct and shearing stresses (Fig. 8) will normally exist at its faces. The subscript of the direct stress symbol indicates the coordinate axis to which a given stress is parallel. Shearing stress τ is marked by two subscripts, one indicates the element where the stress is acting and the other defines the direction of the stress. For instance, τ_{xy} is a shearing stress acting in the element normal to x-axis (the first subscript) and directed along y-axis (the second subscript); τ_{zx} is a stress in the element normal to z-axis and directed along x-axis.

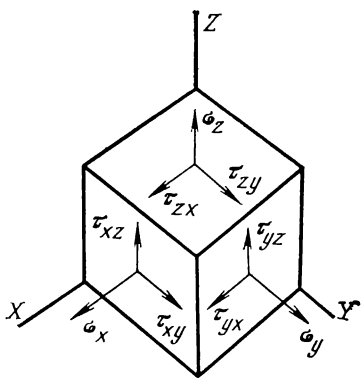


Fig. 8. Direct and shearing stresses at the faces of an elementary parallelepiped

The equilibrium conditions of an elementary parallelepiped determine the equality of shearing stresses: $\tau_{xy} = \tau_{yx}$, $\tau_{xz} = \tau_{zx}$, $\tau_{yz} = \tau_{zy}$. Thus, stress at a point is determined by six stress components: three direct stress components σ_x, σ_y, σ_z and three shearing stress components τ_{xy}, τ_{yz}, τ_{zx}.

The elementary parallelepiped may be defined at a given point in different ways; the magnitudes of direct and shearing stresses acting at the faces of the parallelepiped vary accordingly. There are elements where both direct and shearing stresses are found, and also those where only direct stresses exist, while the shearing ones are nil. Such direct stresses are termed principal and marked by σ_1, σ_2, σ_3 (σ_1 is the highest stress in its algebraic value, σ_3 is the lowest). By using the principal stresses it is possible to represent schematically the stressed state at different kinds of plastic working of metals. The arrows directed to the parallelepiped indicate compression stress, while those pointing outwards, tensile stress. Figure 9*a*, *b*, *c* shows examples of stress diagrams.

There are also elements at which the shearing stresses take the following values:

$$\tau_{13} = \frac{\sigma_1 - \sigma_3}{2}, \quad \tau_{21} = \frac{\sigma_2 - \sigma_1}{2}, \quad \tau_{32} = \frac{\sigma_3 - \sigma_2}{2}$$

These are known as principal shearing stresses. Obviously, τ_{13} is the highest of all principal shearing stresses, since $\sigma_1 \geqslant \sigma_2 \geqslant \sigma_3$.

To characterize the strained state, use is made of the diagrams of principal strains ε_1, ε_2, ε_3. It is assumed that tensile strains are positive and compressive strains negative.

The form of the strained state diagram indicates the ability of a material for plastic deformation.

The plastic deformation proceeds more successfully when realizing the volumetric non-uniform compression diagram. The tensile stresses usually decrease plasticity of a material. By changing the form of

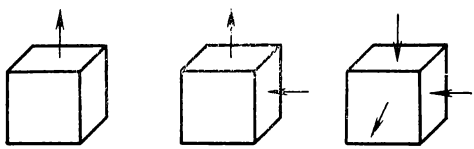


Fig. 9. Strain diagrams
(*a*) one-dimensional; (*b*) two-dimensional; (*c*) three-dimensional

the stressed state it is possible to change the material ability for plastic deformation, i.e. under some conditions the material behaves as brittle, while other stressed state diagrams make it plastic.

At a high hydrostatic pressure under the volumetric compression conditions even such brittle materials as marble display plastic properties. For instance, a marble specimen was deformed for up to 25% in tension and up to 78% in compression.

7. Plasticity Conditions

Plastic forming of a blank involves complex physical and mechanical processes in the material, liberation of heat, creation of residual deformations and stresses. All these phenomena prevent formulation of a plasticity law as simple as, e.g., Hooke's law for elastic strains.

Multitudinous experiments have made it possible to formulate hypotheses on the transition of a metal into a plastic state. The plasticity conditions elaborated by Tresca and St. Venant and von Mises have gained wide recognition today.

According to the Tresca-St. Venant theory, plastic deformation occurs when the maximum shearing stress reaches a limit value of k. The value k is termed plastic constant and is a yield limit in shear τ_y. This plasticity condition also referred to as the maximum shearing stress constancy condition may be represented as

$$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2} = k \tag{12}$$

Plastic constant k can be easily determined by a simple tension experiment, wherein σ_1 is equal to yield limit σ_y, and $\sigma_3 = 0$. Substituting these in equation (12) gives

$$k = \sigma_y/2 \tag{13}$$

Therefore the plasticity condition by Tresca-St. Venant may be written

$$\sigma_1 - \sigma_3 = \sigma_y \tag{14}$$

This condition satisfactorily agrees with the experimental data. However, more accurate experiments revealed minor systematic variations in the behavior of some metals under the plastic conditions from the Tresca-St. Venant theory. Those experiments proved that the yield conditions are influenced by stress σ_2, which, as transpires from equation (14), exerts no effect upon transition of metal into a plastic state.

The Von Mises theory deduces that plastic state occurs when

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma_y^2 \tag{15}$$

The Von Mises plasticity condition is termed the forming specific energy constancy condition. Equation (15) can be obtained when assuming that transition of a metal into a plastic state occurs irrespective of the strained state when the specific potential energy of forming (related to a unit volume) reaches a particular limit.

The Von Mises theory provides for determining the yield limit in shear $\tau_y = k$

$$\tau_y = \sigma_y/\sqrt{3} \approx 0.557\sigma_y \tag{16}$$

The value $k = \tau_y$ which is $0.557\sigma_y$ according to Von Mises better agrees with the experiment for the majority of metals than $k = \sigma_y/2$ deduced by Tresca and St. Venant.

Particular cases of strained state are applicable to many metal-working processes.

With a plane strained state, when deformation in one of the directions (e.g., z) is nil

$$\sigma_z = \frac{\sigma_x + \sigma_y}{2}, \quad \tau_{xz} = \tau_{yz} = 0$$

If the coordinate axes are so selected that $\tau_{xy} = 0$, then the axes x, y, z and stresses $\sigma_x = \sigma_1$, $\sigma_y = \sigma_2$, $\sigma_z = \sigma_3$ will be the principal ones and $\sigma_3 = (\sigma_1 + \sigma_2)/2$.

The plasticity condition takes the form of

$$(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2 = {}^4/_3\,\sigma_y^2 \quad \text{or}$$

$$\sigma_1 - \sigma_2 = \frac{2}{\sqrt{3}}\,\sigma_y$$

For the plane stressed state ($\sigma_z = \tau_{xz} = \tau_{yz} = 0$), the plasticity condition is

$$\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2 = \sigma_y^2$$

8. Methods of Solving Metalworking Problems

The above definitions and equations are used for solving the problems of metalworking. Such problems involve not only the determination of deforming forces which is necessary for selecting the appropriate equipment, but also the analysis of such phenomena as filling of a press tool, local liberation of heat, tool wear, etc.

Various methods are used for solving metalworking problems. Some of them comprise a joint solution of a set of equations based on the equilibrium conditions of the element defined in the deformation centre and the plasticity condition; others use the law of conservation of energy and equate the magnitudes of internal and external forces. To simplify the problem, the deformation zone is divided into separate rigid elements which slip relative to each other. This method, termed the strain energy method, offers diverse possibilities of analysis and relatively simple solutions.

The slip line method has found wide application. In the case of a plane deformation problem, stresses are determined against the orthogonal grid of the slip lines the tangents to which coincide with the directions of the principal shearing stresses. Such grids are plotted on the basis of a number of theorems.

On some occasions the natural pattern of the slip line field can be obtained on the blank surface in plastic deformation (Fig. 10*c*). This natural pattern sometimes found on stamped parts has drawn the attention of scientists. It has been supported theoretically that these lines coincide with the directions of zero compression/tensile strain. Broad application of this method is attributed to the fact that it allows for finding stresses and rates of deformation in the cross sections of the solid subjected to plastic strain, which often constitutes the main problem in the theoretical analysis of the technological tasks.

Experimental methods are used for studying strains and stresses. A coordinate grid is applied to the specimen cross section and is photographed or measured after each increment of strain. The data thus obtained provide for estimating the trajectory of separate points of the deformed solid and rates of deformation, which is sufficient to solve a wide plurality of problems involved in determining the optimum and limit conditions of deformation, evaluating the hazard of destruction, introducing additional steps in pressworking, etc.

Sometimes distribution of stresses in the specimen cross sections is obtained by measuring hardness at different points of the cross section. Knowing the hardness-to-stress ratio for a given material, it is possible to determine distribution of stresses by the hardness values.

When investigating the metalworking processes, it is allowed to assume that the volume of a solid before deformation is equal to its

volume after deformation. This postulate is termed the law of constant volumes. The sizes of the blanks for various kinds of press-working are calculated proceeding from said law.

The maximum permanent deformation that may be imparted to a given material characterizes the ductility of the material. Apart

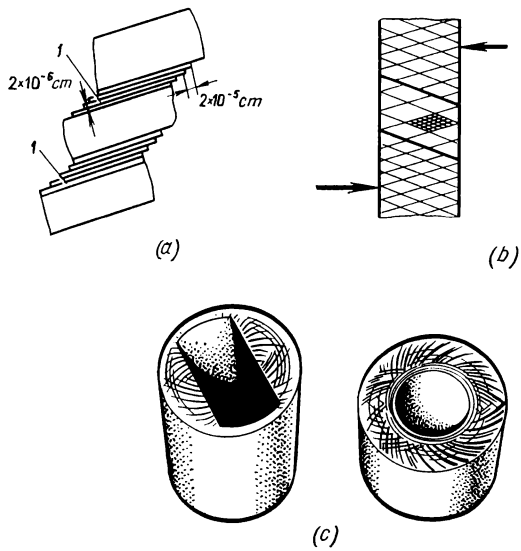


Fig. 10. Diagram of plastic deformation
(*a*) by slipping; (*b*) by twinning; (*c*) natural slip line pattern on the surface of stamped parts

from the material properties, the ductility depends on temperature, rate of deformation, type of loading. As a rule, elevation of the temperature increases ductility, while a rise in the deformation rate decreases it.

9. Physical Nature of Plastic Deformation

Metals and alloys have a crystalline structure in the solid state. In an ideal metal crystal the atoms are arranged in a strictly definite pattern. If the atoms are mentally interconnected by lines, a crystal lattice will be obtained with the points marking the position of the atoms. The entire crystal lattice is essentially a multifold repetition of absolutely identical unit cell systems. Several types of crystal lattice unit cells are known (Fig. 11*a* to *g*).

Three types of crystal structures are most frequently found in metals: a close-packed hexagonal structure, a cubic face-centred and a cubic body-centred structure.

The type of the metal crystal lattice is determined by X-ray inspection. The real crystals never have an ideal structure. They feature various local defects, and are divided into blocks sizing about 10^{-4} cm. Note that the crystal lattice is measured by the values in the order of $(2.8\text{-}6.0) \times 10^{-8}$ cm.

The atoms are so arranged in the crystal that the distance between them and density vary in different directions and planes. The interaction between atoms defines mechanical, physical and chemical

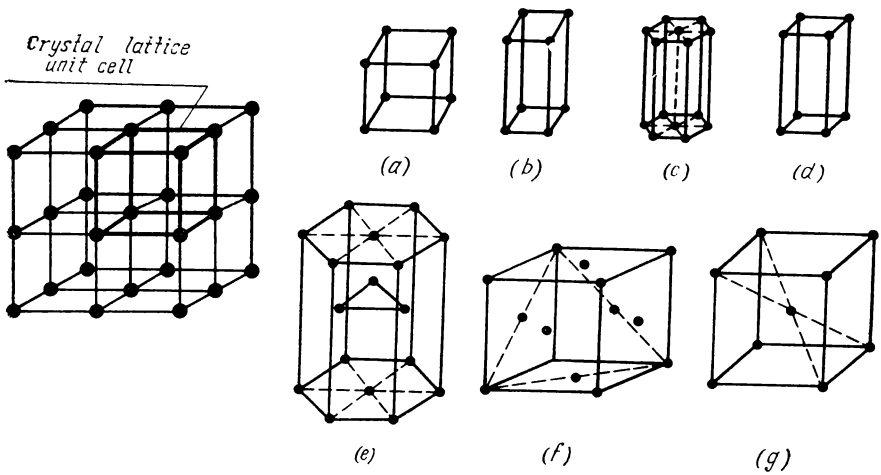


Fig. 11. Crystal lattice of metal and types of crystal lattice unit cells (*a*) cubic; (*b*) tetragonal; (c) hexagonal; (*d*) rhombic; (*e*) hexagonal close-packed; (*f*) cubic face-centred; (g) cubic body-centred

properties of crystals. Owing to different arrangements of the atoms, the properties of the crystal also vary in different directions. The difference in properties depending on the direction is known as *anisotropy*.

The elastic deformation stems from changes of the distances between atoms. By considering the actual arrangement of the atoms and their interaction, it is possible to obtain calculated relationships which are well supported by experiments.

The mechanism of plastic deformation in one crystal (monocrystal) resides in the *shift* (*slip*) of atom layers in particular crystallographic planes along definite directions (Fig. 10*a*). These are the planes and directions of maximum density of atoms. When the shearing stresses in one of the directions reach the critical value, the layers are shifted through about 1 000 interatomic distances.

When the shearing load increases, shifts occur in close slip planes forming a pack of slip planes *1* (Fig. 10*a*). The traces of movement

of the slip plane packs form the slip lines visible by a naked eye (Fig. 10*c*). Regions moving as solids remain between the slip lines. As the deformation develops, the flow of metal becomes chaotic: the number of slip lines increases, parts of the crystal between the slip planes are crushed into blocks and the latter turn.

In addition to slipping, the plastic deformation may occur with *twinning* (Fig. 10*b*). The twinning consists in that one part of the crystal displaces relative to the other. As a result, the first part becomes a mirror image of the second one.

If assuming the crystal lattice to be geometrically ideal, it is possible to calculate the stress required to overcome the interatomic forces. This calculated stress is tens and hundreds of times as high as that determined experimentally, since various defects appear already during crystallization and a perfect crystalline structure does not exist. The defects considerably weaken the crystal.

When a load is applied to real crystals, shearing does not occupy the entire slip plane simultaneously. Slipping starts at the defect location in the crystal and spreads at a considerably lower stress than in the case of a simultaneous slip of the whole block of atoms.

The regions with defects in the crystal lattice, known as *dislocations*, play the main part in the mechanism of plastic deformation. The point of the considerable distortion of the lattice is termed the *dislocation centre*. The dislocations may result from microinclusions getting into the melt, stresses, etc.

The mechanism of displacement of dislocations may be compared with the displacement of a carpet over the floor. The carpet can be moved as follows: shift one end of the carpet to a new place thus forming a hump, then reposition the entire carpet by moving the hump along the latter. The force required for this operation is considerably lower than the force that might be applied for simultaneous repositioning of the entire carpet. Similarly, the dislocations in the crystal provide for plastic deformation by single movements of the atoms rather than the entire crystallographic plane.

The plastic deformation mechanism is well more complicated in the polycrystal. The deformation flows both as an intra- and an inter-crystalline one. The first occurs as in the monocrystal by slipping or twinning, the second, by turning and displacement of some grains relative to others.

The principal deformation involved in pressworking is intra-crystalline deformation since at room temperature the strength of the grain boundary exceeds that of the grain. The plastic deformation of a polycrystal involves deformation of the grain. The grains elongate in the direction of metal flow forming a fibrous structure. In the case of high deformations, the slip planes of separate grains get aligned with the direction of flow.

The pressworking changes the physical and mechanical properties of metal: increases the strength and decreases per cent elongation, diminishes resistance to corrosion, increases electrical resistivity. This combination of phenomena which accompany plastic deformation is called *hardening* (cold working) of metal.

Review Questions

1. What is the difference between elastic and plastic deformation?
2. Explain the essence of Hooke's law.
3. What is the yield point?
4. What is the safety factor?
5. Describe the mechanism of plastic deformation.

Chapter III

PRESSWORKING MATERIALS

1. Metals and Alloys Used for Pressworking

To manufacture parts by pressworking, a wide variety of metals and non-metallic materials are used. These materials arrive at the press shops in the form of sheets, strips, bands and bars.

Metals and alloys are the principal materials of modern machine building. Most of them are capable of permanently changing their shape under the action of external forces without destruction, i.e. capable of plastic deformation.

Pure metals are not frequently used in machine building giving way to their alloys. Metals and alloys are divided into ferrous (pig iron and steel) and non-ferrous (copper, aluminium, zinc, lead, tin, etc.).

Metal for pressworking (steel, non-ferrous metals and alloys) comes in the form of bands, sheets and strips. If metal thickness is up to 4 mm, it is termed "sheet metal", if more, "plate metal".

The ranges of rolled products are indicated in the relevant standards which specify the dimensions of sheets, bands, strips and bars manufactured at the metallurgical works.

For instance, the band in coils may be 2 300 mm wide, whereas its length may reach several tens or, for thin materials, even hundreds of meters.

Sheets may size from 600 × 1 200 to 2 000 × 5 000 mm. Sheets of non-standard dimensions may be manufactured on special order.

Strips come up to 200 mm wide and 2 000 mm long.

Cold die forging relies mainly upon cold-drawn metal in bars, if the diameter exceeds 30 mm, or in bars and coils (bundles), if the diameter is below 30 mm. In the case of mass and large-batch production it is preferable to use coils or bundles, which decreases waste and simplifies automation of material feeding to the press tool.

The bar and coil materials may have round, hexagonal, square and other sections. When selecting material for cold die forging, the required operation properties of the part and metal deformability should be taken into account.

Regular carbon steel is used to manufacture minor parts, domestic articles, and the like. Quality carbon steel is employed for pressworking parts with critical strength and surface finish requirements. Many branches of the machine building industry and especially the automotive industry utilize extensively quality rimming steel (e.g. 05кп, 08кп, 10кп, 15кп according to USSR State Standards) for pressworking. Such a steel keeps on deoxidizing when poured into the ingot moulds so that carbon and silicon burn away additionally and the resulting steel features improved plasticity and high weldability. However, this steel is subject to ageing, i.e. arbitrary change of physical and mechanical properties in storage. Ageing leads to elevated hardness and strength, reduced ductility and appearance of a yield elongation zone on the tensile stress curve, which may result in surface defects during pressworking. Additions or deoxidizers such as aluminium, titanium or vanadium make such steels non-ageing.

To manufacture intricate facing parts (e.g. automobile body parts), use is made of non-ageing steel 08Фкп with a vanadium addition, and killed steel 08Ю or semikilled steel 08Юпс deoxidized with aluminium.

The general-purpose hot-rolled sheet steel delivered with a layer of scale is utilized only for rough building structures, railway freight cars, some types of agricultural machines, etc. Scale covering steel sheets causes rapid wear of punches and dies.

Pickled (annealed and descaled) sheet steel, 0.25 to 3.0 mm thick, is manufactured from mild open-hearth or converter steel. After rolling it is annealed and descaled by pickling. Such a steel offers high ductility and is used for making ware, domestic articles, and also minor parts not to be polished, chrome or nickel plated.

The cold-rolled bright sheet steel is delivered descaled. This steel after hot rolling, annealing and descaling is cold rolled to the required thickness with intermediate or final annealing in a protective atmosphere.

Depending on the surface finish, quality structural sheet steel is divided into four groups: I, II, III and IV (USSR State Standards). The right (higher quality) surface of group I steel sheets of super high finish should be free from any surface defects. For group II sheets (high finish), minor scratches, or light ripples within a half

of the sheet thickness allowance, can be tolerated. The sheets of these two groups are made by cold rolling. The sheets of group III (improved finish) are cold and hot rolled. The right side of the sheet may have scratches, notches, ripples, roll marks within a half of the sheet thickness allowance. Group IV sheets belong to a regular finish group and are manufactured by hot rolling. Pinchers, pinholes, minor scratches and notches, ripples on both sides are tolerable if they do not exceed the sheet thickness allowance. As regards the sheet thickness accuracy, steel is divided into three groups A, B and C (A—high accuracy, B—improved accuracy, C—normal accuracy). Group A includes quality cold-rolled sheets, group B, regular and quality cold- and hot-rolled sheets, while group C consists of regular and quality hot-rolled sheets.

Depending on drawability in the cold state, sheets are divided into three groups: VD—very deep drawing, D—deep drawing and R—regular drawing (in Russian ВГ, Г and Н, respectively, which are the first letters of the corresponding Russian terms).

With respect to its hardness, the cold-rolled low-carbon steel band may be very soft (VS), soft (S), semisoft (SS), low-hardness (LH) and hard (H) (in Russian ОМ, М, ПМ, ПТ and Т respectively); its surface finish is represented by classes I, II and III, while the manufacturing accuracy is defined by the following characters: N (normal accuracy), HW (high accuracy in width), HT (high accuracy in thickness), H (high accuracy in width and thickness) (Н, ВШ, ВТ, В in Russian, respectively); the edges of the band may be untrimmed (UT) or trimmed (T) (corresponds to Russian letters НО and О, respectively).

The black annealed polished plate comes with a thickness from 0.18 to 0.55 mm, while the tin-plate, from 0.21 to 0.55 mm thick. After rolling, annealing and descaling, the plate is additionally rolled to obtain mirror surface which remains dark for the black plate and is plated with a thin layer of tin in the case of tin-plate. The black plate is used to stamp thin-walled parts of domestic articles subject to subsequent painting. Tin-plate is used mainly for making tin cans, various food containers, some thin-walled parts the surfaces of which should be protected against corrosion.

Zinc-plated steel comes in thickness from 0.88 to 1.5 mm. It is manufactured from soft descaled steel and is employed for stamping a wide variety of articles.

To make critical stamped parts, various alloyed structural steels are used. Steels 10Г2А, 12Г2А, 20ХГСА, 25ХГСА (the USSR designation) and some others find wide application in pressworking. The Russian letters in the alphanumerical designations indicate the alloying elements: Х—chromium, С—silicon, Н—nickel, М—molybdenum, Ф—vanadium, К—cobalt, Г—manganese, В—tungsten, Ю—aluminium, Т—titanium, Д—copper. The figures prece-

ding these letters indicate the average carbon content in hundredths of 1 per cent, while the figures following the letters show the percentage of the particular alloying element if it exceeds 1 per cent. The above-mentioned steels feature good ductility and weldability which is important for making stamped-and-welded structures.

Parts of increased corrosion resistance are stamped from stainless steels (e.g. steels 1X13, 1X18H9, 2X18H9, etc.). These chromium- or chromium-nickel-based steels offer satisfactory ductility.

Apart from the above, special-purpose steels, such as electrical-sheet or spring steel, are manufactured.

Sheets or bands consisting of two layers of metal are termed bimetallic. Such sheets and bands may comprise layers of stainless and structural steels, structural steel and copper, etc.

Widening of the range of rolled products and improvement of metal product quality save metal in the national economy. The metallurgical industry of the USSR has mastered manufacture of various new materials: two-layer and multi-layer steel sheets, plastic-clad steel sheets, special-purpose sheet steel, and the like.

Lead-plated sheet steel 08Ю, 0.9 mm thick, is intended to make fuel tanks for automobiles. The lead-tin plating is 6-12 μm thick. The steel is distinguished for improved resistance to corrosive media.

In the automotive, chemical and food industries corrosion- and heat-resistant steels are replaced with cold-rolled steel strip (08кп) chromized in vacuum. The protective layer is 30-100 μm deep. The steel displays good ductility and increased resistance to many reactive media at elevated temperatures. The strip is 1.0-1.5 mm thick and up to 320 mm wide.

Steel strips with a polymeric coating (metal-base laminates) are used in the chemical, automotive, food, and radio engineering industries. The metal-base laminates feature corrosion and wear resistance, good electrical and sound insulation characteristics. The polymer coating is 0.3 mm thick at a steel sheet thickness of 0.5 to 1.0 mm.

The non-ferrous metals which have found wide application in pressworking are aluminium, copper, nickel, magnesium, titanium and their alloys.

Aluminium and duralumin are extensively used in aircraft and automotive industries, for making components of various instruments, domestic appliances, etc. These materials are light-weight, ductile, with a high heat and electrical conductivity. The aluminium grades which are used most commonly are as follows: A1, A2, A3, АД, АД1, those of duralumin: Д1, Д6, Д16.

Copper sheets and bands, grades M1, M2, M3 are employed substantially for stamping parts of electrical equipment. Brass, which is a copper-zinc alloy, is widely used for stamping clockwork parts,

radio components, ware, etc. Brass grades Л62, Л68, Л70 are in general use. The figures following letter Л (stands for brass) indicate the percentage of copper in the alloy. Among other copper alloys used in pressworking is bronze i.e. an alloy of copper with tin, nickel, aluminium.

Nickel H1, H2, H3 and its alloys (German silver and argentan alloy) are utilized for making chemical utensils, instruments, clockwork parts, jewelry.

Magnesium alloys are characterized by light weight, high strength, satisfactory ductility at room temperature and high ductility at a temperature of 350-380°C. Magnesium is 1.5 less heavy than aluminium and 4.5 than steel. Corrosion-resistant magnesium alloys MA1 and MA8 are commonly employed for stamping a wide variety of articles. The ductile magnesium alloys are found in motorcycles, bicycles, trailers and other transport vehicles, in electrical and electronic gear, etc.

Titanium and its alloys offer high strength at a low density. They are finding wide application in pressworking for making vital components in aircraft and some other industries. Some operations in pressworking of titanium are carried out with heating. Titanium alloys BT1-1, BT1-00, BT-5, BT-6, OT4 are in common use.

2. Non-Metallic Materials Used for Pressworking

Non-metallic materials are subjected to pressworking primarily for obtaining sealing, insulating and decorative components.

The following non-metallic materials have found wide use: plastics, rubber, ebonite, paper-based materials (cardboard, fibreboard), mineral materials (mica, micanite).

Plastics are substances produced from wood flour, vegetable fibres, coal tar, gas, oil, peat, etc. They are based on binders which are natural or synthetic resins, derivatives of cellulose, proteins, etc. Fillers, plasticizers and pigments are added to the binder. The fillers may be powders or fibres (paper, cardboard, glass fibre, textile fibre, wood, etc.). The plasticizers make the material plastic while pigments give it the desired colour. The USSR industry produces the following sheet plastics: paper-based laminate, fabric-based laminate, organic glass, vinyl plastic, celluloid.

Paper-based laminate is formed of pressed paper impregnated with synthetic resins, while fabric-based laminate is pressed fabric webs impregnated with the same resins. Of all the pressworking operations, paper-based laminate can be subjected only to blanking; fabric-based laminate, to blanking and, at heating, to bending and drawing.

Organic glass is a transparent material with good electric insulating and corrosion-resistant properties, produced from soda-lime glass. When heated, organic glass is formed readily.

Vinyl plastic is an opaque material with high mechanical, electrical insulating and corrosion-resistant properties, deformable only when heated.

Sheet celluloid may be of a technical grade (white or transparent), aviation grade (transparent), and of a haberdashery grade (various colours). Celluloid is easily formed, especially if heated.

Rubber is used primarily for blanking gaskets and seals for sealing pneumatic and hydraulic systems, insulating electrical apparatuses, decreasing vibration and noise. Owing to its high elasticity, pressing of rubber presents difficulties and the rubber parts are produced mainly by blanking.

Vulcanized rubber with a high sulfur content is employed for producing a hard and viscous material, known as ebonite and distinguished for its excellent electrical insulating properties. Ebonite is deformable at heating.

The main sheet materials based on paper are *cardboard* and *fibreboard*. Cardboard is made from a paper pulp by pressing with subsequent drying, while fibreboard is obtained by treating special paper with a zinc chloride solution. Cardboard and fibreboard can be blanked in conventional press tools.

Mineral materials include mica and micanites. *Mica* is a mineral splittable into very thin shells. *Micanites* are solid opaque materials prepared by gluing crushed mica.

Among other non-metallic materials subject to pressworking are felt, leather, batt, pressboard, etc.

3. Mechanical and Workability Tests of Materials

Any material arriving at a press shop is subjected to a great number of tests. These include general inspection with a view to checking the dimensions and surface condition, as well as chemical, metallographic, mechanical and workability tests.

Chemical analyses are carried out to check correspondence of the chemical composition of a given material to the relevant standard.

Metallographic studies, i.e. studies of the macro- and microstructure, are aimed at determining the ability of a material to deform plastically. The analysis of the macrostructure allows detecting shrink holes, porosity, waviness, cracks, inclusions in metal. It reveals the direction of fibres which is important for bending and some other operations, the nature of cut in blanking. Investigations of the microstructure provide for determining the grain size and nature of the structure. These data are used to estimate workability of a material.

Mechanical properties of a material are found by tensile and hardness tests. The yield point, tensile strength, per cent elongation, per cent reduction in area, uniform elongation and some other parameters

which show that the material is fit for pressworking, are obtained by tensile tests (see Chapter II). The shape and dimensions of specimens are indicated in the respective standards.

The hardness of a material is its capacity to resist introduction into its surface of a harder body. The commonest methods for measuring the hardness of metals are Brinell, Rockwell and Vickers tests. The Brinell hardness number (BHN), showing the hardness of a material, is determined on a hardness testing machine (Fig. 12*a*)

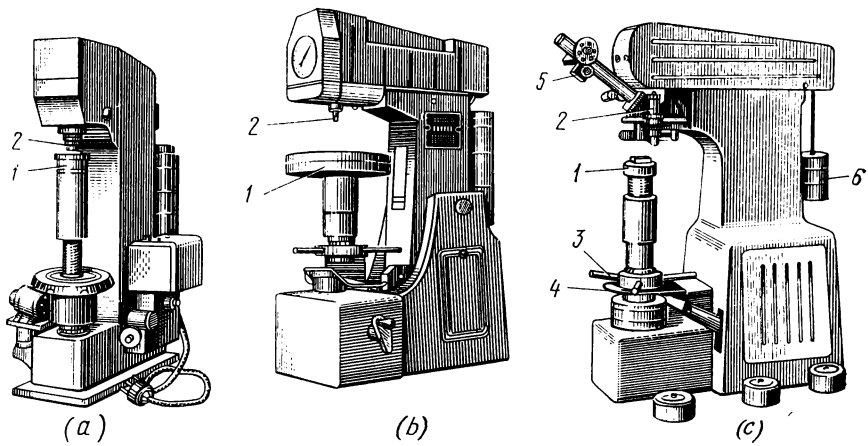


Fig. 12. Hardness testing machines
(*a*) Brinell's; (*b*) Rockwell's; (*c*) Vickers'; *1*—table; *2*—chuck for securing a ball or diamond pyramid; *3*—handwheel; *4*—handle; *5*—microscope; *6*—load

by forcing a steel ball into the surface of a specimen and measuring the diameter of the resulting permanent indentation. This test is applicable for specimens of at least 2 mm thick. A ball of 10 mm in diameter is used to test specimens thicker than 6 mm, a 5-mm ball, for specimens from 3 to 6 mm and a 3-mm ball for those thinner than 3 mm.

On the Rockwell hardness testing machine (Fig. 12*b*), the hardness is determined by the depth of penetration of a diamond cone or steel ball into the specimen surface at various loads: 150 kgf (scale C), 100 kgf (scale B) or 60 kgf (scale A) and the Rockwell hardness is denoted by the letters HRC, HRB and HRA respectively.

The Vickers diamond pyramid hardness test (the testing machine is shown in Fig. 12*c*) consists in measuring the diagonal of the impression made by a quadrangular diamond pyramid with an angle of 136 degrees at the apex. The pyramid is secured in chuck *2* while the specimen is positioned on table *1*. The table is lifted by handwheel *3* till the plane of the specimen contacts the pyramid. Then

loads *6* which force the pyramid into the metal are applied by handle *4*. The length of the impression diagonal is measured using microscope *5*. Knowing the measured length of the impression diagonal and the value of the load applied, the hardness number is determined from the tables. When measuring the Vickers hardness, loads of 0.049, 0.098, 0.294 and 0.981 kN (5, 10, 30 and 100 kgf) are applied. Light loads provide for determining the hardness of surface layers of parts that were subjected to surface hardening, nitriding, etc.

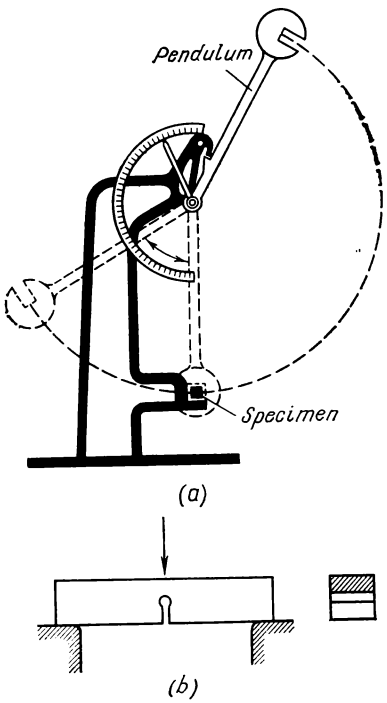


Fig. 13. Impact testing diagram (*a*) and specimen (*b*)

Special conversion tables are available for converting hardness numbers from one scale to another.

The Rockwell testing machine is used to test metal thicker than 0.5 mm, the Vickers machine, thicker than 0.15 mm. Microhardness tests are employed to determine the hardness of thinner sheets.

On some occasions metal is subjected to compression, bending, torsion, impact and fatigue tests.

The ability of a metal to resist impact load, i.e. the *impact strength*, is checked on impact testing machines (Fig. 13*a*). A notched specimen (Fig. 13*b*) is fixed at both ends in the testing machine and is struck by a heavy pendulum. The metal toughness is estimated by the deflection of the pendulum when the specimen ruptures.

Materials for components that will operate under alternating loads are tested for fatigue. The tests are performed on special machines according to the type of load (bending, tension, etc.) and the frequency of its alternation (from a few per minute to several thousands). *Endurance (fatigue) limit* is the term applied to the maximum stress a material can resist at a specified number of repeated loads without failure.

Metal also has a tendency to deform plastically when loaded over a considerable period of time at stresses lower than the yield point. This type of deformation is known as *creep*. The creep limit is the

stress whereat deformation of a metal occurs at a given temperature at a particular rate (e.g., elongation by 0.1 per cent at a 10 000-hour test).

To determine the fitness of a material for a particular pressworking operation, *workability tests* are carried out.

Sheet materials intended for stamping operations are tested for shearing, bending, unbending, drawability.

Shearing tests are conducted to find the resistance of a given material to shear. These tests are usually performed with a simple blanking punch on a testing machine and the suitability of the material for cutting operations is estimated by the test results.

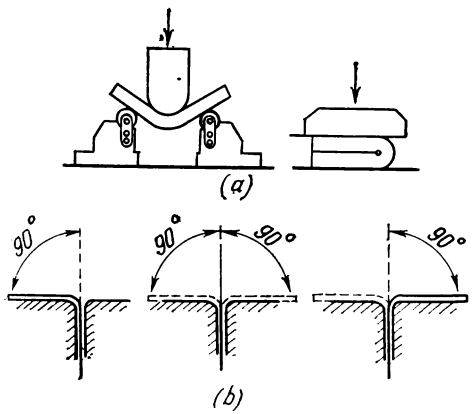


Fig. 14. Workability tests of sheet metal in bending (*a*) and in bending-and-unbending (*b*)

Bending and bending-and-unbending tests determine the possibility of metal bending. To perform the bending test, a plate specimen is positioned on rolls (Fig. 14*a*) and a punch is pressed against it. The specimen must bend without cracking. Depending on the purpose of the tests, the specimen is bent through a definite angle or till its edges meet. In the bending-and-unbending tests a plate specimen cut from a sheet or band is vised and bent/unbent through 90° in both directions (Fig. 14*b*). The number of times it can be bent backwards and forwards through 180 degrees until it breaks is usually given in the relevant standards or specifications for the metal.

An important workability test of a material that is to be subjected to bending operations is the spring back test the results of which are used to form the spring angle-to-bending radius relationship.

The suitability of a material for drawing (cupping tests) is determined on the Erichsen machine (Fig. 15*a*) or other testing apparatuses which simulate the drawing process.

With the *Erichsen tester*, specimen *3* (Fig. 15*b*) is clamped between die *1* and clamp *4*. Punch *2* is forced against the clamped piece. The properties of the metal are estimated by the depth of the cup produced before the specimen begins to fracture. Punch *2* is fed by a screw rotated with handwheel *5*. The appearance of fracturing is determined with the aid of mirror *6*. The depth of the cup must correspond to the values given in the relevant standard.

These tests are used for sheet metal up to 2 mm thick.

The manual Erichsen machine can be replaced with the МТЛ-10Г tester. In addition to extruding spherical cups, this machine performs cupping tests by drawing a cylindrical cup and flaring holes. The depth of extrusion or drawing is noted at the moment of force drop. Apart from the depth of the cup, the form of the rupture and quality of metal in the cup apex are considered.

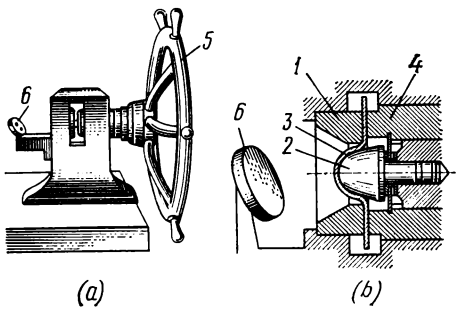


Fig. 15. Erichsen tester
(*a*) general view; (*b*) diagram of operation

Sheet metal is also subjected to such workability tests as drawing of cylindrical cups in press tools to determine the limit degree of drawing, forcing through of a strip (tension bending test) to measure the depth of extrusion and elongation; flat specimen twisting and the like.

The workability test results are used to give recommendations for employing the material studied. The production experience is also taken into account in this case. For instance, steel with an ultimate strength of up to 33 kgf/mm^2, per cent elongation of at least 33-45 per cent, hardness of up to BHN 38-52 and extrusion depth of at least 10-12 mm will suit for deep drawing.

Metal intended for cold die forging is subjected to *upsetting* and tensile tests in the cold state. After upsetting, the standard specimen is checked for cracks.

Review Questions

1. What metals are widely used in pressworking?
2. Name the non-metallic materials used in pressworking.
3. What hardness testing methods do you know?
4. How can a material fitness for drawing be determined?

Chapter IV

MEASURING TOOLS AND INSTRUMENTS

1. Basic Definitions

To measure stamped pieces, parts of press tools and presses, various measuring instruments are used at the press shop. The measuring means include graduated measuring instruments, ver-

nier measuring tools, micrometer-type tools, indicators, etc.

The measuring instruments are chosen by their metrological characteristics the main of which are the scale division value, scale division spacing, permissible error, measuring range and measuring force.

The scale division value is the difference between the values of two adjacent divisions on the scale. For instance, divisions of 0.5 mm are applied to the micrometer barrel scale, while the thimble scale has divisions of 0.01 mm (Fig. 17). The scale division spacing is the distance between two adjacent divisions. This distance is usually from 1 to 2.5 mm.

The permissible error of a measuring device is the maximum error with which the instrument is allowed for use.

The maximum and minimum dimensions that can be measured with a given instrument define its measuring range. For instance, vernier caliper ШЦ-1 has a measuring range of from 0 to 125 mm.

The measuring force is the force created when the measuring surfaces contact the workpiece in the course of measurement.

Measurements are divided into absolute and relative. In absolute measurements the value to be determined is read directly off the scale of a measuring tool or instrument. For instance, when a workpiece was measured with a micrometer, a size of 14.68 mm was obtained. In relative measurements the deviation of the size being measured from that of a reference part (standard) or preset value is determined. For instance, an indicator set to zero against a reference part will show the deviation of the workpiece size from said reference.

2. Linear Measurements

Linear dimensions are checked by steel rules, stacks of gauge blocks, vernier tools, micrometer-type tools, etc.

A *graduated steel rule* (Fig. 16*a*) is used to measure dimensions to the accuracy of 1 mm.

A *vernier caliper* (Fig. 16*b*) offers the accuracy of 0.05-0.1 mm. External dimensions are measured by jaws *1* and *9*, internal ones—with jaws *2* and *3*, the depth of recesses, with depth-measuring rod *7*. Thumb screw *4* is used to clamp sliding head *5* and fix the measurement taken.

The dimension is read with the aid of vernier *8*. Vernier scale *6* accurate to 0.1 mm has 10 divisions over a length of 9 mm. The divisions are spaced through 0.9 mm, which is 0.1 mm less than the spacing of the beam scale.

If the vernier is moved to the right from its initial position, then when its first graduation gets aligned with the first graduation of the beam scale, the zero of the vernier scale will move 0.1 mm from the beam scale zero. A gap of the same size will be between jaws *1*

and *9*. With further movement of the vernier to the right, the vernier scale divisions 2, 3, 4, etc., will successively coincide with the corresponding divisions of the beam scale.The distances between the zeros

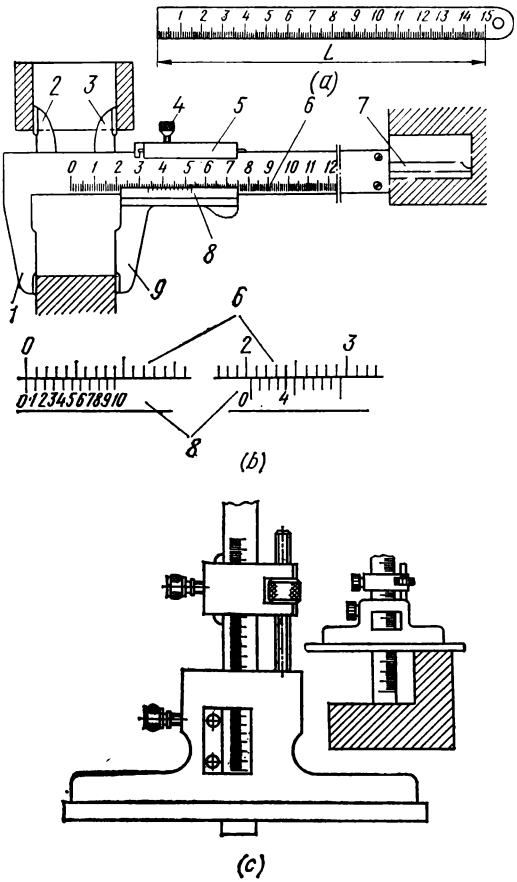


Fig. 16. Steel rule (*a*); vernier caliper (*b*); vernier depth gauge (*c*) and example of vernier depth gauge use (*d*)

and between the faces of the measuring jaws will accordingly increase by 0.2, 0.3, 0.4 mm, etc.

When using a vernier caliper, the distance between its jaws (hence the dimension being measured) in whole millimetres is read off the beam scale up to the division which precedes the vernier scale zero. The number of tenths of a millimetre is determined by the number of vernier divisions up to the one coinciding with the beam scale division. Fig. 16*b* shows the position of the vernier reading 20.4 mm.

A *vernier depth gauge* (Fig. 16*c*) is used to measure the depth of holes, slots, the height of steps, etc., with the aid of a sliding beam.

A *vernier height gauge* is intended to measure the height of workpieces positioned on a bench plate.

To measure dimensions to the accuracy of 0.01 mm and higher, use is made of micrometers (Fig. 17), micrometer depth indicators

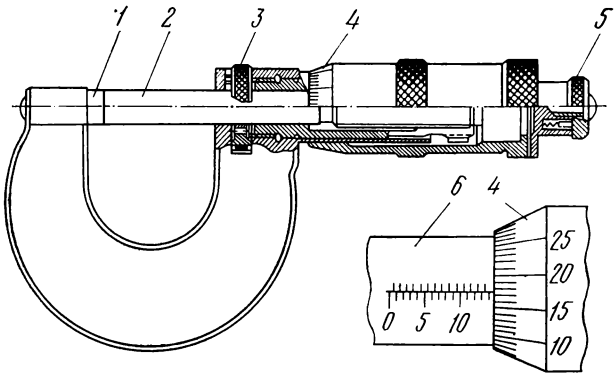


Fig. 17. Micrometer

and inside micrometers. In a *micrometer caliper*, measuring anvil *1* is stationary, while measuring spindle *2* is moved by a high-precision screw which sets it to the dimension being measured.

To ensure adequate measuring accuracy and avoid elastic strains which may appear if an excessive force is applied while driving in the screw, the latter is moved by means of ratchet *5*. As soon as a certain pressure is reached, ratchet *5* starts slipping and the screw stops.

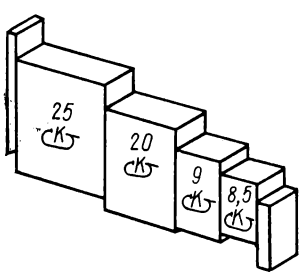


Fig. 18. Gauge blocks

The reading is taken off the scale of barrel *6* with divisions of 0.5 mm. The scale of thimble *4* has 0.01-mm divisions. The number of half millimetres is read off the barrel scale and the remaining number of hundredths of a millimeter of the dimension, off the thimble scale. Fig. 17 shows the dimensions $14.5 + 0.18 = 14.68$ mm. To fix the dimension, lock ring *3* is used. The micrometer depth indicator and inside micrometer are used according to the same procedure.

The *gauge blocks* (Fig. 18) are intended to check and adjust various measuring means. As regards the certification accuracy, the gauge blocks are divided into 5 classes (the first class is the highest). The gauge blocks are delivered in sets. To determine the required size, a stack of several gauge blocks (up to four in all) is formed by wrin-

ging them to each other. The gauge block surfaces are thoroughly finished and the adhesion forces retain the blocks together with a sufficient strength.

The kits of gauge blocks belonging to classes 2 to 5 are used by the manufacturers; those of class 1, by the metrological laboratories.

All measuring means are subject to verification with the use of gauge blocks within specified terms. The verification results are entered in the measuring tool cards or certificates.

3. Instruments for Checking Surface Straightness and Flatness

The deviations of a surface from flatness or straightness are checked by different methods. In pressworking such checks are usually performed with the use of a straight-edge and a feeler gauge. A straight-edge is laid in various directions on the surface being checked and the gap between the straight-edge precision face and the surface is measured with a feeler gauge. On some occasions straightness of a cylinder or taper is checked by means of a straight-edge which is laid on the surface, and inspection is made to see if light appears between the surface and the straight-edge; if the surface is flat, light will not be apparent. The gap is compared with that of a master sighting gap. With certain experience and adequate illumination, this method may be accurate to 2 μm.

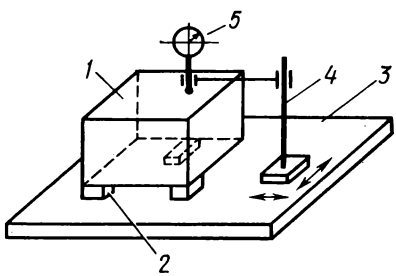


Fig. 19. Diagram of flatness and straightness checks

Flatness and straightness may be also checked by the paint pattern method. A thin layer of paint is applied to wide straight-edges or surface plates and they are moved over the surface to be checked; the protruding parts of the surface will be painted and the nonflatness is estimated by the number and area of the painted parts.

One of the procedures for measuring deviations from flatness and straightness is as follows (Fig. 19). Workpiece *1* is placed on plate *3* by three supports *2*. Stand *4* with dial indicator *5* is moved in different directions. The difference between the maximum and minimum readings of the dial indicator is the deviation of the workpiece surface from straightness.

Horizontal positions of surfaces, their deviations from flatness and straightness are often checked by various levels: frame, bar, micrometric, and the like.

Horizontal position, straightness and flatness are estimated by the position of an air bubble in a vial filled with ester or ethyl alcohol. The frame levels are intended to check horizontal and vertical surfaces and are divided into three accuracy groups. The levels belonging to the first group have a scale division value of from 0.02 to 0.05 mm over a length of 1 m (or from 4 to 10″). The bar levels are used to check straightness and flatness of horizontal surfaces.

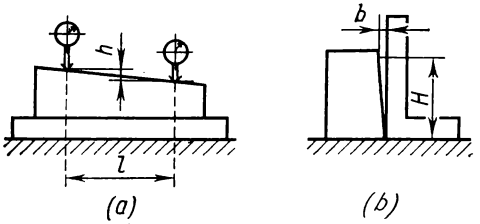


Fig. 20. Surface position checks (*a*) deviation of planes from parallelism (by value *h*); (*b*) deviation from squareness (by value *b* at height *H*); *l*—relative length

In micrometric levels reading is taken off the scale of a micrometric head with a division value of from 0.1 to 0.01 mm per 1 m of length.

Parallel misalignment between two planes is determined by a surface plate and a stand with a dial indicator (Fig. 20*a*) while non-squareness, by a try-square with a feeler gauge or dial indicator (Fig. 20*b*).

4. Tools for Measuring Angles and Tapers

Used for shop measurements of angles are integral or composite try-squares, angle gauges and bevel protractors (Fig. 21*a*, *b*, *c*). The vernier *bevel protractors* have found wide application. They provide for measuring angles to the accuracy of 2′. The angle being measured is set between fixed blade *1* and movable (measuring) blade *2*. A semicircular dial *3* is rigidly secured to the fixed blade; sector *4* with a taper is attached to the movable blade. The movable blade with sector rotates about pivot *5*. To measure acute angles, acute angle attachment *6* is mounted on the measuring blade.

Obtuse angles (from 90° to 180°) are measured without the acute angle attachment but 90° are added to the scale reading.

Tapers are usually checked by indirect measurements, i.e. linear dimensions are measured rather than the angles and the angles are calculated from the measurement results. *Sine bars*, calibrated rollers and balls are used for the purpose. To measure taper angle 2α with a sine bar (Fig. 22), workpiece *1* is positioned on table *2* to which rollers *3* are attached. The distance between the rollers is L. A stack of gauge blocks is placed under one of the rollers. The height of the stack is calculated from the formula

$$h = L \cdot \sin 2\alpha$$

The deviation of the actual angle from the nominal value is read off dial indicator *4* in its two positions over length *l*. If height *h* of the stack is so selected that reading of the dial indicator does not

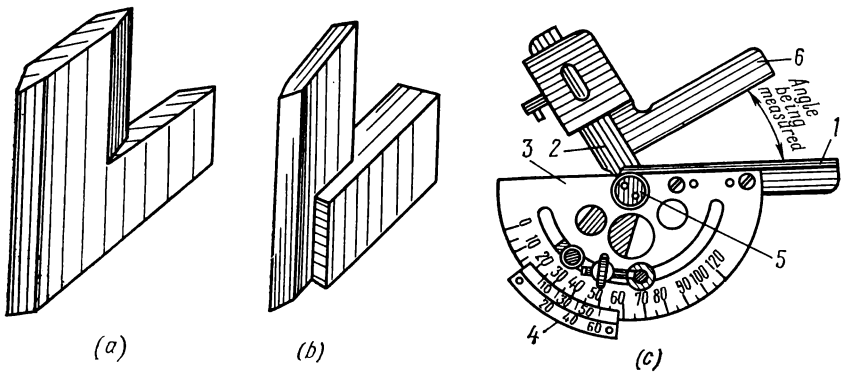


Fig. 21. Angle measuring tools
(*a*) integral square; (*b*) composite square; (*c*) vernier bevel protractor

change throughout length *l*, the *h*/*L* ratio will define the sine of actual angle 2α, and the angle is found in the trigonometric table from the known sine.

When *measuring tapers with rollers* (Fig. 23*a*), distances l_1 and l_2 between the rollers are determined for the rollers positioned on the

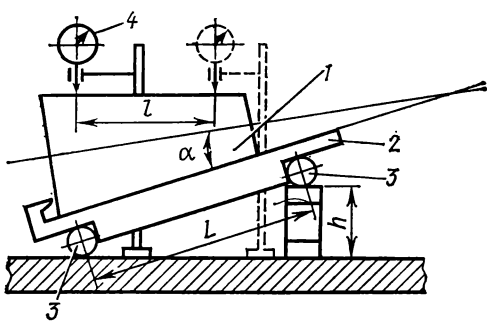


Fig. 22. Diagram of taper angle measurement on sine bar

surface plate and on the gauge block stacks with a height of *h*. The taper angle is calculated from the formula

$$\tan \alpha = (l_2 - l_1)/2h$$

Internal tapers are measured by two balls, dia *d* and *D*, and a depth gauge (Fig. 23*b*). By inserting first the smaller and then the larger ball and measuring sizes l_1 and l_2 by a depth gauge, the taper

angle is determined from the formula

$$2 \sin \alpha = \frac{2(D-d)}{2(l_1-l_2)-(D-d)}$$

In addition to the above methods, various gauges are widely used for checking external and internal tapers.

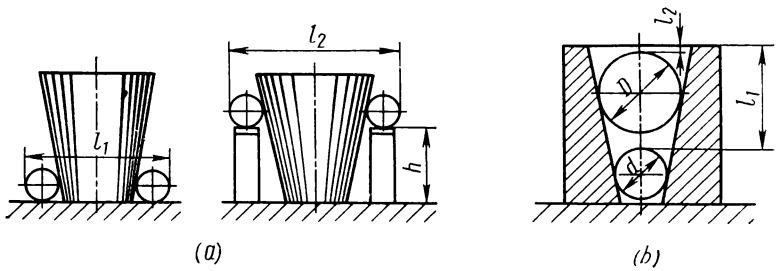


Fig. 23. Diagrams of measuring taper angle with calibrated rollers (*a*); with calibrated balls (*b*)

5. Instruments for Relative Measurements

Often it is necessary to measure the deviation from a particular value rather than the absolute value of a size. Various indicators, and also instruments without scales (gauges, templates, feeler gauges, thread gauges) are used on such occasions.

The *dial indicators* (Fig. 24) are intended to perform measurements to the accuracy of 0.01 mm. The indicator includes a measuring stem the middle part of which has a rack. A displacement of the rack causes rotation of a pinion, and hence of the indicator pointer coupled with it. The indicator has two scales. The hundredths of a millimetre are read off the main scale, the number of millimetres, off the smaller scale.

The indicator scale is turnable so that if the pointer zero position is not vertical, the scale is turned and its zero is aligned with the pointer initial position.

The indicators are mounted on special stands and supports. By moving the workpiece relative to the dial indicator, e.g. over the marking-off plate, or by moving the indicator with its support relative to the workpiece along the plate, it is possible to check deviation from flatness or parallelism of the surfaces being checked.

The dial indicators may be fitted to the depth gauges, thickness gauges, wall-thickness gauges.

In addition to the rack-and-pinion type dial indicators there are lever-and-pinion and spring-type dial indicators which differ in

the construction of transmission for converting translatory motion of the measuring stem into the rotary motion of the pointer. The reading accuracy of such indicators is 0.001 and 0.000 2 mm respectively.

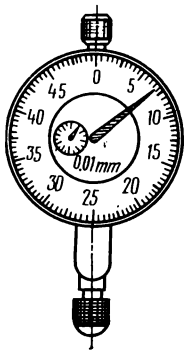


Fig. 24. Dial indicator

In mass production, when the same sizes are checked, *limit gauges* are extensively used. The limit gauges include plug gauges for checking holes and snap gauges for checking shafts (Fig. 25*a* to *e*). The limit gauge has no readout devices. Such gauges are intended only to check whether deviations of a given size are within the drawing tolerances. The limit gauge has two sizes: tolerable and untolerable. For instance, a plug gauge intended to check a round hole diameter has one end which should enter the hole (the "go" gauge) and the other, should not (the "no-go" gauge). If the second ("no-go") end enters the hole, its diameter is beyond the permissible limits and the workpiece is rejected. The snap gauges for checking diameters of shafts or other linear dimensions, thread plug and ring gauges for measuring internal and

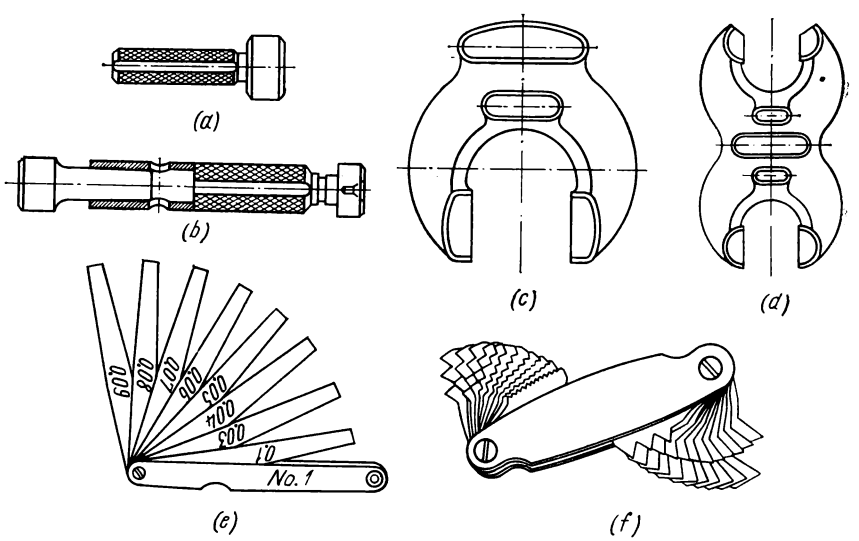


Fig. 25. Non-indicating gauges
(*a*), (*b*) single- and double-ended plug gauges; (*c*), (*d*) single- and double-ended snap gauges; (*e*) feeler gauge; (*f*) thread pitch gauge

external threads, respectively, are based on the same principle. Thread plug and ring gauges are used to check the pitch diameter

and plain snap and plug gauges, the outer diameter of thread.

The gauges for checking tapers are made with steps or marks. The end face of the taper being checked should be within the step (Fig. 26*a*), or between the marks (Fig. 26*b*).

When checking sizes with gauges, it is impermissible to apply excessive forces.

Clearances between two mating parts are measured with feeler gauges, which are a set of steel blades of different thickness (several tenths or hundredths of a millimetre). The clearance is measured by inserting one or several blades of the gauge between the mating surfaces. Each blade is marked with its thickness.

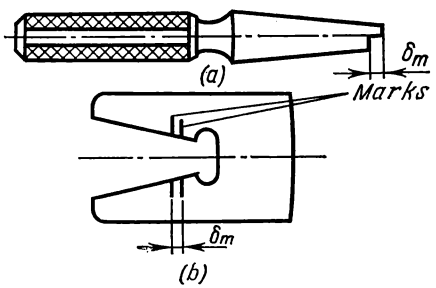


Fig. 26. Taper gauges
(*a*) plug gauge; (*b*) snap gauge

Shaped surfaces are checked with templates such as step templates, depth templates, height templates, templates with marks, etc.

Thread pitch gauges are used to measure a thread pitch. Similarly to the feeler gauge, the thread strip gauge comprises a number of blades (Fig. 25).

Measuring tools are very sensitive to shocks. Their surfaces may be attacked by corrosion and they may wear with time. Therefore, they should be stored with extreme care and verified regularly by the factory measuring instrumentation laboratory.

Review Questions

1. What is the scale division value?
2. How is a vernier designed?
3. How is a micrometer used for measurements?
4. Name the measuring instruments without scales you know.

Chapter V

PRINCIPAL OPERATIONS OF SHEET STAMPING

1. Basic Definitions

A *production process* is a combination of actions directly connected with changing the shape, dimensions, properties and condition of a blank. A production process consists of separate operations.

An *operation* is a part of a production process, performed by one or more workmen (team) on one machine and involving all the successive actions required for machining a blank (for instance, blanking, drawing, bending, etc.).

A *step* is a part of an operation. When using combination press tools, an operation comprises several steps. For instance, with a compound or progressive press tool, two or more steps, e.g. blanking and piercing, blanking and bending, etc., may be combined within one operation.

A completed action of a worker (for instance, bringing a blank to the tool, placing it in the die, etc.) is called an *operation element* or *manipulation*.

In pressworking, operations are divided into steps, and the latter, in turn, may consist of several manipulations.

A production process includes production operations, quality control operations and transportation operations (transfer of blanks or workpieces from one machine to another).

A *blank* is a material intended for the first production operation; a *workpiece* is a partially machined blank intended for subsequent treatment.

Sheet stamping is pressworking of parts from sheet, band or strip material accomplished without a substantial change in its thickness. Sheet stamping is used for working steels, plastic non-ferrous metals and their alloys, and some non-metallic materials. Thin sheets of metal (up to 4 mm thick) are usually worked cold, while plates thicker than 4 mm may be processed both in a cold and in a hot state.

Sheet stampings are distinguished for their high accuracy. Sometimes they require finishing on metal-working machines: trimming, drilling small diameter holes, etc.

The main advantages of sheet stamping are as follows:

(a) the possibility of producing strong, light and rigid thin-walled components or products of a simple or intricate shape, which are difficult or impossible to manufacture by other methods;

(b) a high output and reduction of scrap;

(c) strong possibilities for automation with the use of relatively simple means;

(d) interchangeability and high surface finish of parts.

Sheet stamping is used for making small parts of watches and instruments, medium-size parts, e.g. metal utensils, tin cans, components of bicycles and motorcycles, various blanking covers, caps, discs, brackets; large facing parts for motor cars, buses and tractors, such as bodies, fenders, doors, roofs; parts of aircraft and railway car bodies; and, finally, very large and heavy parts made of thick plates, such as bottoms of steam boilers and tanks, marine hull components, etc.

Sheet stampings can be welded to produce complex and critical machine components, such as pressed and welded frames of presses and beds of metal-working machines, intricate pressed and welded automobile bodies, parts of chemical apparatus, components of river and sea-going vessels. These are much stronger, lighter and cheaper than components made by casting.

Over 70 per cent of motor car parts, over 80 per cent of business machines, about 95 per cent of consumer goods are made by stamping.

Sheet metal stamping comprises the following operations:

(a) cutting operations, in which one part of a blank is severed from the other;

(b) forming operations, in which the shape of blanks is changed without destroying them;

(c) combined operations, including both cutting and forming steps;

(d) stamping assembly operations, in which separate sheet stampings are mechanically integrated.

2. Cutting Operations

Cutting operations include shearing, blanking, punching, trimming, slitting, scrapless piercing, shaving.

Shearing is a complete separation of a part of a blank (Fig. 27*a*), or cutting a blank into pieces (Fig. 27*b*) along a straight or curved line.

Blanking is cutting along a closed contour to produce a flat stamping of the required outline (Fig. 27*c*).

Punching is making of through holes in a blank (with scrap removal) (Fig. 27*d*).

Trimming is separation of a work from scrap (Fig. 27*e*).

Slitting is a partial separation of a part of a blank (Fig. 27*f*).

Piercing is making of through holes in sheet blank (without scrap removal) (Fig. 27*g*).

Shaving is removal of minor irregularities along the inside or outside contour of a workpiece after blanking or punching to obtain accurate dimensions and required finish (Fig. 27*h*).

In pressworking shops, sheets and strips are cut into narrower pieces or separate blanks by means of shears with parallel or inclined blades, circular shears having one or more pairs of blades, punching and vibration shears, and on presses using cutting tools.

Blanking, punching, shaving, shearing and slitting are performed on presses carrying corresponding press tools.

Three stages are distinguished in cutting metal:

1. The punch slightly compresses and bends the metal, presses into it and forces it into the die (Fig. 28*a*).

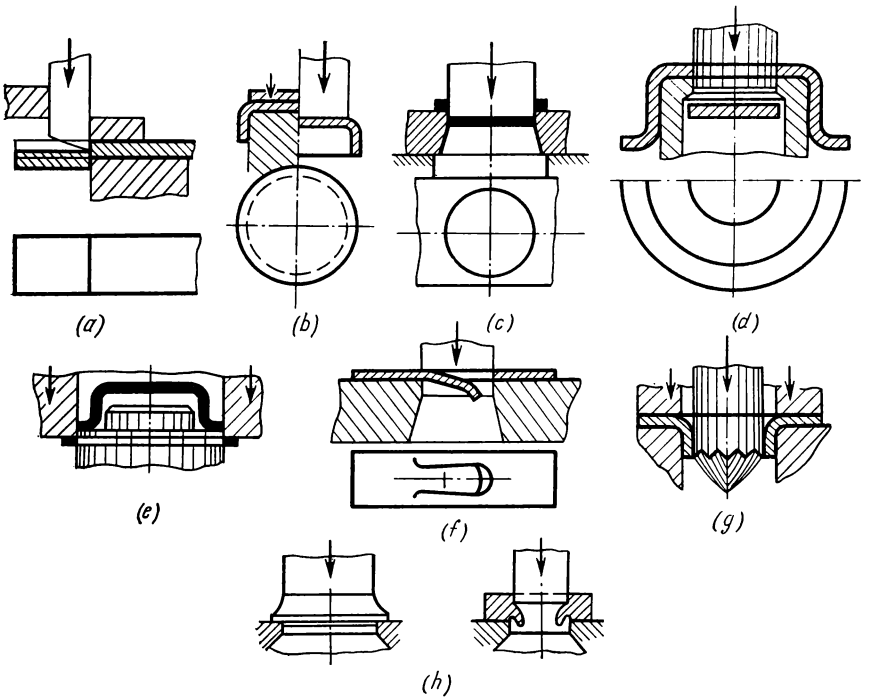


Fig. 27. Cutting operations

(a), (b) shearing; **(c)** blanking; **(d)** punching; **(e)** trimming; **(f)** slitting; **(g)** piercing; **(h)** shaving

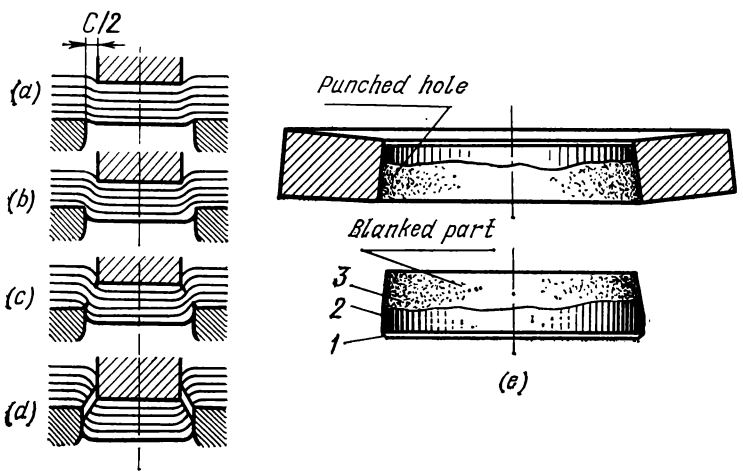


Fig. 28. Metal cutting stages

(a) initial pressing in of punch; **(b)** cutting of fibres; **(c)** formation of shear cracks; **(d)** separation of metal; **(e)** punched hole and blanked part

2. Further pressing of the punch into the metal results in severing of metal fibres with the punch cutting edge from the top and with the die edge from the bottom (Fig. 28*b*).

3. Further motion of the punch leads to shearing cracks appearing in the metal (Fig. 28*c*), which combine and cause complete separation of the stock (Fig. 28*d*).

To make the shearing cracks meet, a definite clearance must be provided between the punch and the die ($C/2$ per side), depending on the properties, condition and thickness of the material being cut. When the clearance has been properly selected, the cracks spreading from the cutting edges of the punch and the die meet.

The section and outline of the blanked part and punched hole are shown in Fig. 28*e*. The surface of the blanked part has three clearly visible zones corresponding to the three cutting stages. The first is zone of initial cutting *1*. The second is bright cylindrical belt *2*, which is the zone of the cut made by the punch or die. The third zone is rough tapered dull surface *3* (shearing surface) which ends in a small crushing surface. The surface of the punched hole has the same zones, but arranged in the reverse order.

The clearance between the punch and the die has a great influence on the force required, the wear and life of press tools, and especially on the quality and accuracy of stampings. With a small clearance, a second bright belt with burr and uneven edge is produced in the upper part of the workpiece. This results from the shearing cracks not meeting, but running parallel to one another so that the metal ruptures between them. With a larger clearance, when cutting this stock, the metal is drawn into the clearance and breaks off forming jagged edges on the stamping.

When cutting thick material, a large clearance results in the stamping having a pronounced rounded-off edge on the side of the die. If the clearance varies along the contour of the workpiece, a part of the stamping may have burrs. Besides, the non-uniform clearance increases the working force and leads to rapid blunting of punch and die cutting edges.

The value of diametral clearance C (mm) (Fig. 28) for blanking and punching can be found from the formula

$$C = mt$$

where t is the thickness of the stock, mm, m is a variable factor allowing for the kind of operation, thickness and properties of the stock.

For regular blanking and punching $m = 0.05$ to 0.2; for finish blanking—0.02 to 0.04. In each particular case it is necessary to use production reference books and manuals which contain tables indicating the values of m.

In the course of time the punches and dies wear and the clearance between them increases. Therefore, the clearance in a new press tool should be minimum (C_{min}).

For blanking, the dimensions of the stamping D_{st} are assigned to the die, while the clearance is obtained by decreasing the dimensions of the punch, D_p, i.e.

$$D_p = D_{st} - C$$

For punching, on the contrary, the size of the hole is given to the punch and the clearance is obtained by increasing the dimensions of the die, D_d:

$$D_d = D_{st} + C$$

The design cutting force F in simultaneous cutting of the stock over its entire contour is found from the formula

$$F = fLt\tau_{sh} \text{ N (kgf)}$$

where L is the length of the cutting line or perimeter of the cut-out contour, mm; f is a factor allowing for the condition of the punch and die cutting edges, material thickness variation, etc., usually assumed to be 1.25 to 1.3, t is the stock thickness, mm; τ_{sh} is the shear strength, MPa (kgf/mm^2).

For instance, τ_{sh} is assumed to be 25-30 kgf/mm^2 for low-carbon steel; 45-52 kgf/mm^2 for medium-carbon steel; 16 kgf/mm^2 for soft copper; 52 kgf/mm^2 for bronze БрА7; and 21 kgf/mm^2 for annealed aluminium alloy Д16АМ.

In blanking and punching the punch is tightly enveloped by the metal. To remove the metal from the punch a certain force is to be applied. This force is usually approximated at $0.1F$.

Accuracy in blanking and punching. Regular blanking or punching ensure accuracy of classes 3 and 4. To increase the accuracy, use is made of press tools with sturdy guide posts and the stock is held down mechanically at cutting. The accuracy of blanking/punching depends on the kind of material, method of cutting, design of a press tool and its condition, sharpness of cutting edges, etc. The accuracy of blanking and punching is also strongly influenced by the value and distribution of the clearance along the blanking contour.

Methods of decreasing blanking and punching force. Blanking or punching of a sheet material in press tools with parallel cutting edges occur simultaneously throughout the workpiece contour, which may require a sufficient force. To decrease this force, press tools having inclined cutting edges of the punch or die are used. When such press tools are employed, the cutting force decreases since shearing occurs gradually along the contour.

There are punches and dies having cutting edges inclined inward (Fig. 29*a*), outward (Fig. 29*b*), and with cutting edges formed by the

intersection of two cylinders whose axes are perpendicular to each other (Fig. 29*c*).

The angle of shear is made symmetrical and at both sides to avoid lateral forces. This angle φ (Fig. 29) is taken equal to 2-8°. Depending on the cutting operation, either a die or a punch can be sheared. For blanking, the die is sheared and the face of the punch is flat, thus producing a flat stamping and curved scrap. For punching, the punch is sheared, while the die remains flat.

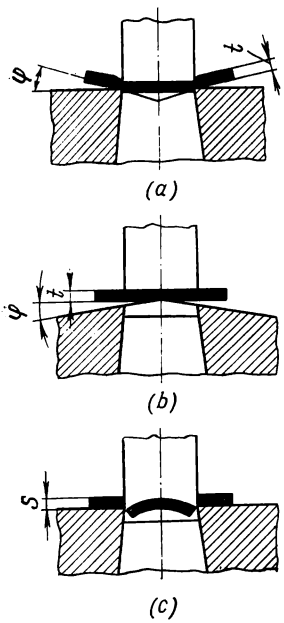


Fig. 29. Blanking and punching using press tools with sheared faces

(*a*) with die faces inclined inward; (*b*) with die faces inclined outward; (*c*) with punch cutting edges formed by intersection of two cylinders with relatively perpendicular axes

To make several holes in one blank on the same press tool, punches of different lengths are used so that the holes are not punched simultaneously and the required force is decreased.

Finish blanking and punching. There are several methods of finish blanking and punching. Among them are: finish blanking in a die with rounded cutting edges (Fig. 30*a*), finish blanking using a punch whose size exceeds that of the die (Fig. 30*b*), finish punching with a punch having rounded cutting edges (Fig. 30*c*) and finish blanking using a clamp with a wedge-shaped edge (Fig. 30*d*).

When the first method is used, at the beginning of pressing the workpiece is greater than the die owing to the rounded edges of the latter. In the course of blanking the excess metal is compressed and the cut surface of the stamping gets polished.

Such a method of stamping, also called blanking with compression, is used in watch making and instrument industry for manufacturing small gears, ratchets and other components from non-ferrous metals and soft steel.

Finish punching with a punch having rounded cutting edges is performed in a similar way. When using a punch with the dimensions exceeding the corresponding dimensions of the die, the punch is stopped 0.2-0.5 mm short of the die. The workpiece is pushed through the hole in the die when the following blanks are stamped. This method is used in finish blanking of soft non-ferrous metals and alloys 0.5 to 5.5 mm thick.

When blanking with the use of a clamp having a wedge-shaped rib, a workpiece is cut from a blank pre-compressed by the penetrating rib. This method ensures a cut finish of class 8. The unilateral clear-

ance between the punch and the die is about 1 per cent of the material thickness. Parts produced by finish blanking or punching usually require no further treatment and are suitable for immediate mounting or operation. This method is used to produce parts of typewriters and sewing machines, radio and TV sets, automobile drum and disc brakes, a variety of electrical components, and the like.

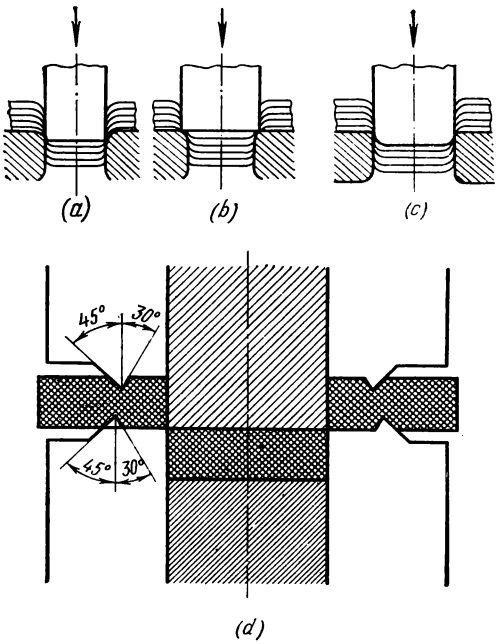


Fig. 30. Finish pressworking operations

(*a*) blanking in a die with rounded cutting edges; (*b*) blanking with a punch greater than the die; (*c*) punching with a punch having rounded cutting edges; (*d*) blanking with a blankholder having a wedge-shaped edge

In addition to the above methods, use is made of finish blanking or punching with holding down the workpiece at a high pressure of 50-60 kgf/mm^2 (0.5-0.6 MPa) and finish punching of small holes with a continuously guided punch. Such a method is employed to make small- and average-size parts and rules out the need for dressing. Holes with a diameter of 0.3 stock thickness having a high finish of the cut surface are punched using tools with a continuously guided punch.

Rubber-pad blanking and punching are used mainly in small-batch production for making very large stampings from thin sheets of steel (up to 1 mm thick), duralumin (up to 1.2-1.3 mm) and aluminium (up to 2 mm thick).

A steel template acting as a punch is placed on the bolster plate (Fig. 31*a*). The part of the die is played by a rubber pad contained in a metal holder (or without a holder). The template is about 10 mm

high; while the rubber pad is 4 to 5 times as thick. Blanking is effected as follows. The blank is placed on the template, the press slide is lowered, the rubber die presses the blank to the template (punch), bends away the overhanging edges of the blank and presses them against the bolster plate. Further travel of the slide results in these edges being severed along the punch contour. Rubber-pad punching is similar to blanking, the difference being in the use of a steel die and a rubber punch (Fig. 31*b*).

Rubber-pad cutting can be used for simultaneous blanking and punching or blanking and shaping of a depression. The rubber-pad

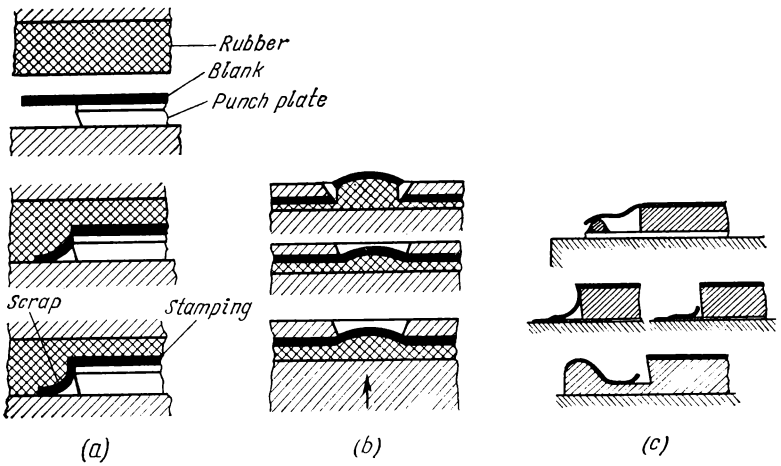


Fig. 31. Rubber-pad blanking and punching
(*a*) blanking; (*b*) punching; (*c*) clamping devices for reducing waste

blanking and punching are advantageous in the use of simple and inexpensive tools. The disadvantage is a limited thickness of the material worked, large amount of scrap, jagged (rough) edges of the stamping which should be worked additionally.

Rubber-pad blanking is normally performed on special hydraulic presses and less frequently on crank or other machines. To reduce scrap, various clamping devices are used (Fig. 31*c*).

Rubber pads may be replaced with those made from polyurethane which is a high-strength, wear-resistant and elastic synthetic material. These properties of polyurethane provide for obtaining quality stampings without subsequent trimming of edges.

Shaving is used for improving the accuracy and finish of the workpiece cutting surface after blanking or punching. Contour shaving is performed in a shaving press tool. A shaving allowance is left in blanking or punching. The total allowance for shaving consists of

the clearance C between the punch and the die and a special allowance for shaving σ (Fig. 32).

The outer contour can be shaved with a punch smaller in size (Fig. 32*a*) or larger than the die (Fig. 32*b*). In both cases the wide part of the workpiece is placed on the die, i.e. shaving is performed in the same direction as blanking. When shaving with a punch greater than

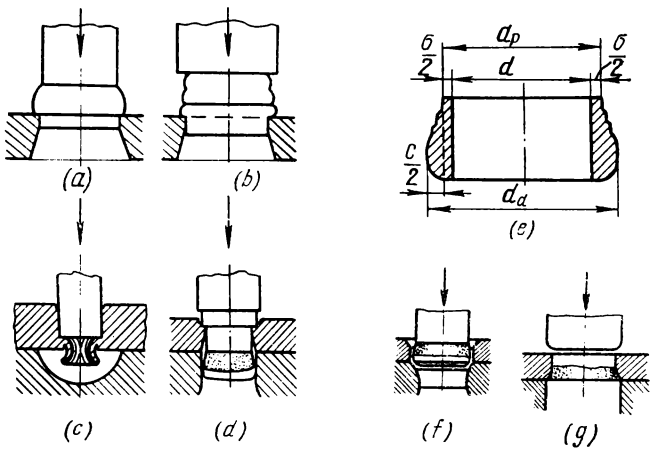


Fig. 32. Shaving and sizing

(*a*) shaving with a punch smaller than the die; (*b*) shaving with a punch greater than the die; (*c*) shaving of hole; (*d*) piercing and shaving with a stepped punch; (*e*) diagram of allowance construction; (*f*) sizing by pressing a workpiece through a tapered die; (*g*) sizing with a punch having rounded cutting edges; diameters: d—workpiece diameter; d_p—punch diameter; d_d—die diameter

the die, the punches are not fitted to the die which considerably cuts their manufacturing cost.

To obtain higher accuracy and surface finish, especially with intricate stampings, two or even three shavings are performed in succession. Shaving ensures surface finish of class 7 and even higher.

In shaving small-diameter holes the allowance is cut off only by the punch, a plate with depressions serving as a die (Fig. 32*c*). As in punching, the workpiece is placed on the die. The small hole shaving accuracy is 0.01-0.03 mm per diameter.

To make accurate holes up to 12-15 mm in diameter in non-ferrous metals and soft steel up to 3 mm thick, simultaneous punching and shaving is practised using a stepped punch (Fig. 32*d*). The punch pierces the hole with its lower end, shaves it with the first step and sizes with the second ensuring the required accuracy and surface finish. A drawback is rapid wear of the shaving step of the punch. Besides, the method necessitates clamping of the work. Fig. 32*e* shows construction of allowances.

In addition to shaving, squeeze sizing is used to improve surface finish. The outer contours of small parts are sized by pushing the work through a die with a tapered hole (Fig. 32*f*), and holes—by driving a punch with rounded edges (Fig. 32*g*).

Surface finish improves to class 8. Blanking and shaving are often performed in one press tool with the blanking and shaving dies arranged one above the other.

Cutting of non-metallic materials. Stampings of plastics, organic glass, fabric-based laminates, etc. are blanked by punches with

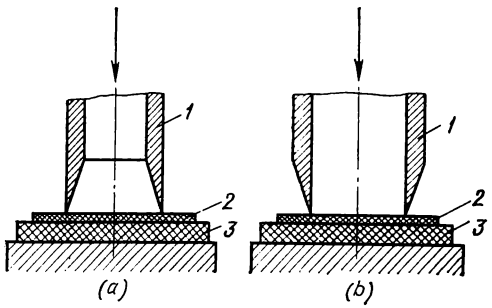


Fig. 33. Cutting of non-metallic materials
(*a*) punching; (*b*) blanking; *1*—punch; *2*—material; *3*—pad

sharp cutting edges. If such materials are worked in regular press tools, cracks and chipping may result. Some brittle materials are blanked when heated. Cardboard, paper, fibreboard and celluloid stampings are made with ordinary tools. Parts of fibrous and elastic materials (rubber, leather, felt) are made with cutting punches (Fig. 33*a*, *b*), which are the cutters having the form of the part. Cutting is performed on a pad of wood, plastic, etc.

3. Forming Operations

Forming operations include bending, twisting, drawing, ironing, flanging, beading, bulging, reducing, embossing, straightening and some others (Fig. 34*a-l*).

Bending is a formation or change of angles between blank parts or imparting of a curvilinear shape to a blank (Fig. 35*a* to *f*). In bending, the metal layers adjacent to the inner surface are compressed at the bend, and the layers disposed on the outer side are tensioned in the longitudinal direction (Fig. 35*a*). The reverse takes place in the lateral direction, therefore the shape of narrow and sufficiently thick stampings is distorted at the bend. The layer of a blank which is neither tensioned nor compressed is called the neutral layer or plane.

Accurate dimensions are usually obtained by completing the bending operation with a finish strike at the punch, thus ensuring good contact between the latter and the blank.

To improve bending accuracy, use is made of blankholders which press the blank to the punch. Free bending may lead to displacement of the blank, hence decreased accuracy of the stampings. Finish forming and clamping of the blank ensure accuracy of class 3 or 4 for bent stampings.

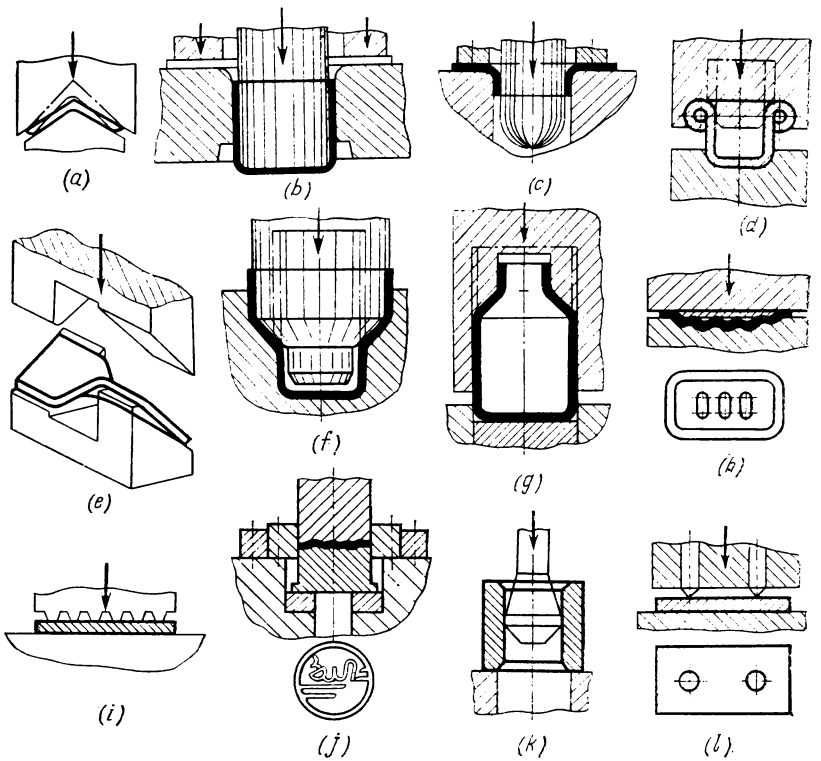


Fig. 34. Forming operations
(*a*) bending; (*b*) drawing; (*c*) flanging; (*d*) beading; (*e*) twisting; (*f*) bulging; (*g*) reducing; (*h*) embossing; (*i*) straightening; (*j*) coining; (*k*) sizing; (*l*) dotting

The correct location of the bending line with respect to the direction of the metal fibres is of great importance in bending. The bending line should be substantially normal to the direction of fibres (Fig. 36*a*, *b*). On some occasions, the angle between the bending line and the direction of fibres may be decreased to 45°. Smaller angles and small radii of bending may result in fracture of the material.

The length of a blank for bending is calculated from the length of the neutral layer which is at about 0.3-0.5 the thickness from the inner surface of the bend (Fig. 35*a*).

Minimum permissible bending radii. Small radii of bending may lead to breaking or cracking of the work. To prevent this, approximate values of the minimum radii of bending are established (Table 1).

Table 1

Minimum Bending Radii in Fractions of Material Thickness

Direction of bending line	Materials				
	aluminium, copper, brass, Л62	steel 10, steel 20	steel 55, soft duralumin	steel 65, steel 70	bronze, hardened duralumin
Across rolling fibres	0	0.1	0.5	1.0	2.0
Along rolling fibres	0.4	0.5	1.5	2.0	3.5

Spring back. Elastic deformations cause spring back of the work after bending, i.e. a change in its dimensions (Fig. 36*b*). To compensate for spring back, the angles of the punch or die are changed accordingly or the tool is made with a compensating device (Fig. 37*a* to *d*).

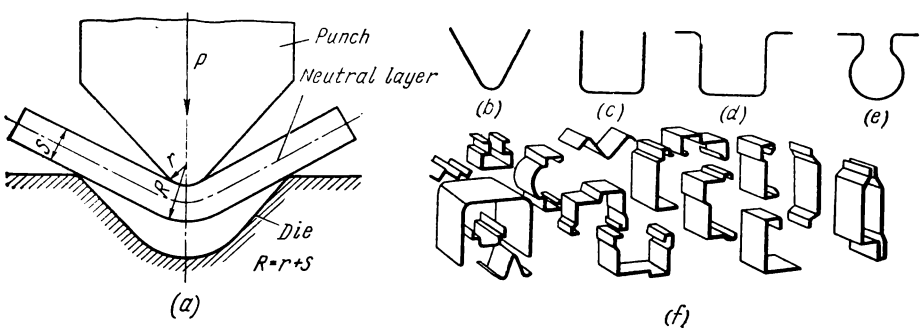


Fig. 35. Bending

(*a*) diagram of bending process; *R* and *r*—outer and inner radii of bending; *S*—material thickness; kinds of bending: (*b*) single (V-shaped) bend; (*c*) double (U-shaped) bend; (*d*) quadruple bend; (*e*) bend with a round element; (*f*) parts produced by bending

The amount of spring back depends on the properties and state of the material, its thickness, the shape of the work and the radius of bending. For instance, in free bending without finish forming of a workpiece made from soft steel up to 0.8 mm thick, with $r/S < 1$, the spring-back angle $\beta = 4°$, and with $r/S > 5$, it is 6°.

For hard steel with $\sigma_u = 600$ MPa (60 kgf/mm^2) β equals 7 and 12°, respectively.

If a part is to be bent with a zero radius on the punch side, the blank may be subjected to preliminary reduction of the cross section

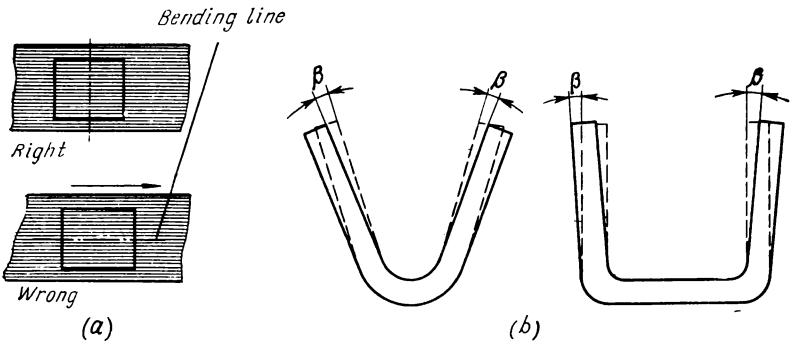


Fig. 36. Direction of bending lines (*a*) and spring back (*b*) (the arrow shows the direction of the fibres)

for about a half of the material thickness (Fig. 38). Such a method is practicable if weakening of the part is not critical.

To preclude play of the blank in the course of bending, it is sometimes fixed in the press tool by making production (auxiliary) holes.

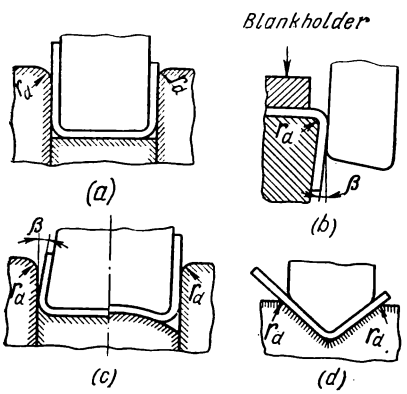


Fig. 37. Compensating for spring back

(*a*) bending with thinning of side walls; (*b*), (c) making a punch or die with compensating angle correction; (*d*) bending with sizing

Stretch bending. It is difficult to bend a thin workpiece with a large radius, since the blank springs back to its original shape. Stretch bending is used on such occasions (Fig. 39). In stretch bending blank *1* is clamped at the ends with clamps *2* and is then bent along the contour of punch *3* while stretching for 2-5 per cent of its original length.

Rubber-pad bending. Thin sheets can be bent with the aid of rubber pad *1* (Fig. 40*a*, *b*) enclosed in steel holder *2*. Rubber-pad bending is used mainly in small-batch production. The press tools for rubber-pad bending are cheaper than all-metal ones, since one of their deforming components (punch or die) is replaced by a universal rubber pad.

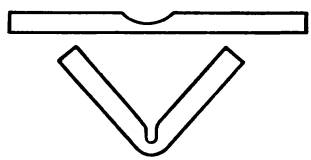


Fig. 38. Reducing blank thickness for bending without radius on punch side

The value of the force in free V bending can be found from the formula

$$F = (1.6\text{-}1.8)\frac{Bt^2}{l}\sigma_u \text{ kgf (MN)}$$

where F is the bending force, kgf (MN), B is the strip width, mm, σ_u is ultimate tensile strength, kgf/mm^2 (MPa), t is the thickness of the material, mm, l is the distance between the supports, mm.

The value of clearance C_b between the die and punch in bending depends primarily on the material thickness. With the clearance less than the optimum one, the bending force increases, the material gets thinner in the bending zone and various defects (dents, etc.) may appear on the workpiece surfaces. The value of clearance in

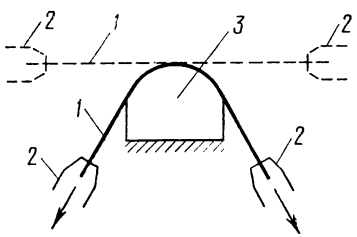


Fig. 39. Stretch bending

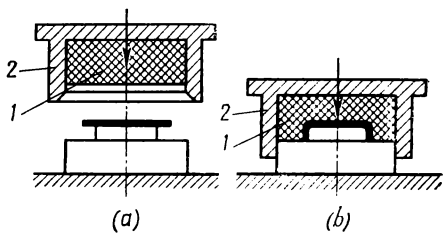


Fig. 40. Rubber-pad bending
(*a*) before bending; (*b*) after bending

bending steel can be assumed approximately to be $C_b = (1.05\text{-}1.15)\ t$, in bending aluminium, $C_b = (1.0\text{-}1.1)\ t$.

To increase wear resistance of the punches and dies, and decrease the required force, the blank surfaces are lubricated before bending.

Workpieces with a great radius of bending can be produced from sheet metal on bending rolls. The sequence of steps (*1-8*) for forming a cylindrical article by rolls is shown in Fig. 41.

Drawing is shaping flat or hollow blanks into hollow component *2* (Fig. 42*a*).

Drawing is characterized by the draw-reduction ratio R_{dr}. For the first draw $R_{dr} = d_1/D_{bl}$, where d_1 is the diameter of the workpiece, mm, D_{bl} is the diameter of the flat blank, mm.

In drawing, flat blank *5* (Fig. 42*a*) is forced by punch *1* into the hole of die *3*. The flange of the blank experiences considerable compressive stresses which may lead to wrinkles (Fig. 42*b*). To prevent wrinkling, blankholders *4* (clamp plates) are used.

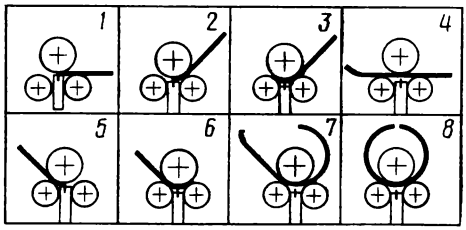


Fig. 41. Roll forming

The blankholders should be used for flat blanks when

$$D_{bl} - d_1 \geqslant 22t$$

or

$$\frac{t}{D_{bl}} \times 100 \leqslant 4.5\,(1\text{-}R_{dr})$$

The value $\Delta = (t/D_{bl}) \times 100$ is termed the blank relative thickness.

In drawing, the thickness of the blank changes somewhat. In the zone of the bottom bend when drawing cylindrical cap *2* (Fig. 42*a*),

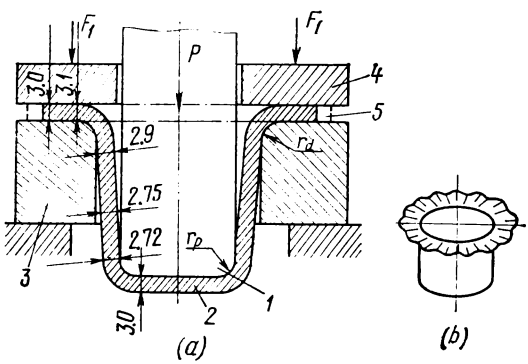


Fig. 42. Diagram of drawing (*a*) wrinkles formed in flange when drawing without blankholder (*b*)
r_d, r_p—rounding radii of die and punch, respectively

the thickness decreases by 10-18 per cent or more; at the upper edges it grows by 15-25 per cent.

The cylindrical part of the blank being drawn experiences considerable stresses. When the stresses exceed the ultimate tensile strength of a given material, the cap bottom breaks off. To prevent breakage of the bottom, the draw-reduction ratio R_{dr} must be kept

within certain limits. Deep stampings which cannot be drawn in one step with ensuring the required strength are drawn in several steps.

In drawing, the edges of the workpiece are not even owing to non-uniform flow of metal in different directions with respect to fibres. Therefore, the edges should be trimmed after drawing.

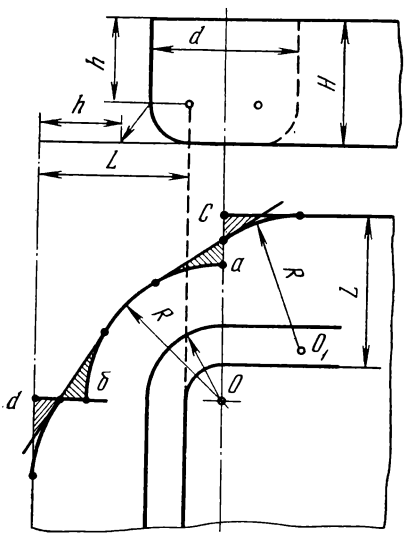


Fig. 43. Plotting layout of blank for drawing rectangular box-shaped part

The dimensions of the blanks for drawing are determined on the assumption that the volumes of the blank and of the stamping are equal, ignoring changes of the material thickness involved in drawing. Thus, the condition of equality of volumes is reduced to the condition of equality of areas of the blank and the drawn workpiece. To determine the dimensions of a blank for drawing a solid of revolution on the above assumption, first the total area of the part, A, is found and then the blank diameter is calculated from the formula

$$D_{bl} = 1.13 \sqrt{A}$$

To find the surface area A, the drawn workpiece is divided into simple geometrical elements, and the areas of their surfaces are calculated and summed up. The diameter of a blank for drawing a cylinder with a flat bottom can be determined from a simplified formula

$$D_{bl} = \sqrt{d^2 + 4dh}$$

where d is the external diameter of the cylinder, mm, and h is the cylinder height, mm.

Formulas for determining the surface areas of various solids of revolution are given in the reference books on sheet stamping.

When calculating the dimensions of a blank for drawing, an allowance is sometimes made for trimming the work edges. These allowances depending on the workpiece height h and the ratio between the height and the diameter d are given in reference tables.

In drawing box-shaped hollow parts, the shape and dimensions of blanks are also determined proceeding from the equality of the blank and workpiece surfaces. It is assumed that only box corners are subjected to drawing, while the walls are obtained by bending.

Therefore, the dimensions of the blank in the wall zones are found from the formulas for bending, while the corner zones are calculated on the assumption that the corners are formed by drawing a quarter of a cylindrical cap. An arc of the radius R_{bl} of said conventional blank is used to connect the wall contours at points *a* and *b* (Fig. 43). Tangents to this arc are drawn through the middle of lengths *ac* and *bd* and the resulting angles are rounded off using the radius R_{bl}.

Computing the drawing forces. The force required for drawing a cylindrical workpiece in a tool with a blankholder is approximately determined from the formula

$$F = F_1 + F_2$$

wherein the drawing force $F_1 = n\sigma_u A_1$ and the clamping force $F_2 = pA_2$.

In these formulae n is a numeric coefficient the value of which is selected from reference tables depending on the draw-reduction ratio R_{dr} (for instance, with $R_{dr} = 0.55$ for the first draw, $n = 1.0$; with $R_{dr} = 0.70$, $n = 0.60$, etc.), σ_u is the ultimate tensile strength of the blank material, kgf/mm^2 (MPa), A_1 is the cross section area of the workpiece cylindrical portion through which the drawing force is transmitted, mm^2 (m^2); p is the clamping pressure, kgf/mm^2 (MPa), A_2 is the area of contact between the clamping plate (blankholder) and the blank at the initial moment of drawing, mm^2 (m^2).

The values of p are found in reference books; they are 0.2 to 0.3 kgf/mm^2 for soft steel, 0.08 to 0.12 kgf/mm^2 for aluminium, 0.1 to 0.15 kgf/mm^2 for copper, and 0.15 to 0.20 kgf/mm^2 for brass.

When selecting the clamping force, it should be taken into account that insufficient force will lead to wrinkling, while excessive one, to breakage of the bottom. The value of clamping pressure p depends on the degree of deformation, thickness and properties of the material, and also on the clearance between the punch and die.

In single-action presses the clamping devices are actuated by springs, elastics, hydraulic or pneumatic drives. If pneumatic cushions are used, the clamping force is easily adjusted and maintained during the working travel.

Draw-reduction ratio and determining the number of steps. A workpiece should be drawn using the least possible number of steps (draws). On the other hand, the stresses in the workpiece critical cross section should not exceed its ultimate tensile strength, which is ensured by proper selection of the draw-reduction ratio R_{dr}.

The number of steps depends on the total value of the required drawing and on the permissible value of drawing per step which is determined by R_{dr}. The value of R_{dr} is found in the reference tables depending on the kind and condition of the blank material, its relative thickness Δ in view of a certain safety factor. In practice, the

value of R_{dr} for soft steel and $\Delta = 1.5\text{-}1.0$ is assumed to be 0.50 to 0.53 for the first draw, from 0.75 to 0.76 for the second draw, etc.

Geometry and dimensions of punches and dies. Depending on the work to be drawn, the punches and dies may be cylindrical, tapered, spherical, rectangular, shaped, etc. Their working edges are rounded off and the rounding radius values influence greatly the drawing force, the degree of deformation, the probability of wrinkling of the flange, etc.

Too small a radius at the die edge may lead to fracture of the blank owing to unfavourable conditions for metal deformation and increased friction losses. With large radii the conditions of drawing are more favourable, but wrinkles are more likely to occur. Therefore, when a die edge radius is great, special blankholders are used (Fig. 44).

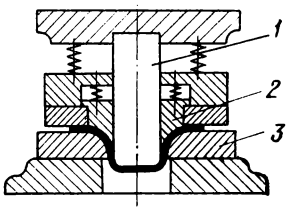


Fig. 44. Drawing with the use of a special blankholder
1—punch; *2*—special blankholder; *3*—die

The edge radii of dies, r_d, can be selected on the basis of the following approximate equations: for works of soft steel $r_d = (4\text{-}10)\ t$, of brass and aluminium $r_d = (3\text{-}5)\ t$, etc. The punch edge radius for a single-step drawing operation is taken equal to the required radius of the workpiece but not less than the minimum permissible radius indicated in reference books. In multi-step drawing, the optimum radius of punch edge rounding for all the draws except the last one is taken from reference tables. For the final step, the rounding radius is also selected to equal that of the workpiece. The punch (die) diameter or respective cross section dimensions (when drawing non-round parts) are so selected as to obtain a workpiece of the desired size and ensure a unilateral clearance between the punch and die to be 1.35-1.50 of the deformed metal thickness.

Special kinds of drawing. Drawing inside out is a combination of two or more drawing steps within one travel of the press tool. Each succeeding draw is directed opposite to the preceding one (Fig. 45*a*, *b*, *c*). The *drawing inside out* is used to decrease the number of press-working operations.

Multi-layer drawing is used to obtain several hollow parts such as basins, pans, plates, etc. at a time by working two or three stacked layers of thin sheet material. This increases labour productivity and increases the relative thickness Δ of the blank (owing to a number of layers) thus preventing wrinkling.

Hollow parts can be produced by *successive draws* in a strip (Fig. 46*a*, *b*) with the use of multi-station tools. To prevent fracture of the strip, the draw-reduction ratio R_{dr} should be selected somewhat larger than in regular drawing. For instance, when drawing parts from low-carbon

steels and brasses, $R_{dr} = 0.68\text{-}0.72$ for the first draw and 0.80-0.85 for the second.

Ironing is a drawing operation involving thinning of walls to a desired degree (Fig. 47*a*). In ironing, the length of the workpiece increases at the expense of wall thinning. Normally, the thinning of walls

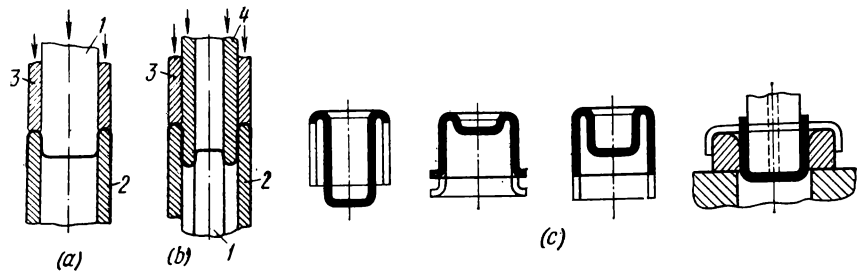


Fig. 45. Drawing inside out
(*a*) single; (*b*) multiple; (c) parts produced by the drawing inside out method; *1*—punch; *2*—die; *3*—blankholder; *4*—punch-die

in one draw does not exceed 30-35 per cent of the original thickness which is ensured by selecting the appropriate clearance between the die and punch. The workpiece bottom thickness remains unchanged. Ironing can be performed simultaneously through several dies arranged one after another (Fig. 47*b*). Fig. 47*c* shows a diagram of the ironing press tool.

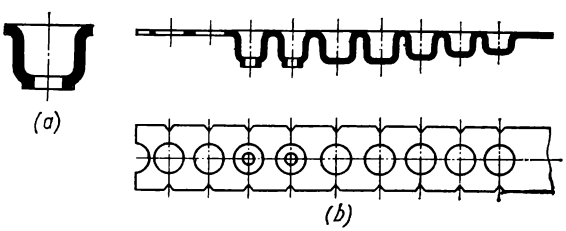


Fig. 46. Successive draws in strip
(*a*) part; (*b*) sequence of steps

To decrease the friction force when drawing a material through a solid tapered or spherical die, there are constructions of dies with balls or rollers secured in them. Replacement of sliding friction with rolling one provides for a considerable increase in the degree of deformation within one step.

When drawing large-size thin sheet components of intricate shapes (automobile facing parts, components of chemical reservoirs, bot-

toms, hulls, etc.), use is made of drawing ribs or bars to reduce wrinkling and equalize the tensile stresses in various areas of the blank. The construction of the hold-down surface of a press tool for complex drawing is an important and labour-consuming task.

To stamp large-size thin-walled bottoms, special and combined methods of forming have been elaborated. These include drawing of blanks with pre-formed stiffening ribs, which is effected in two

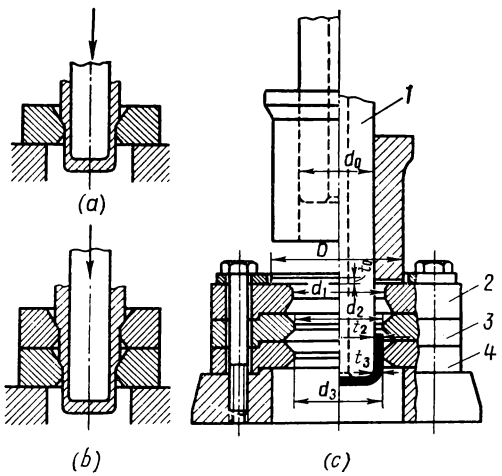


Fig. 47. Ironing
(*a*) through one die; (*b*) through several dies; (*c*) diagram of a press tool; *1*—punch; *2*, *3*, *4*—dies

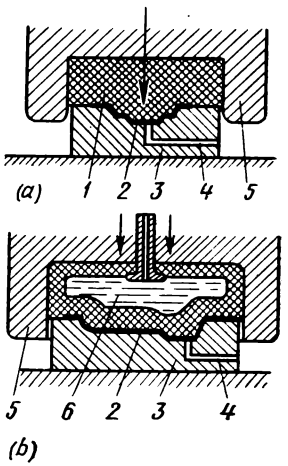


Fig. 48. Drawing
(*a*) with a rubber pad; (*b*) with liquid; *1*—rubber punch; *2*—workpiece; *3*—die; *4*—air vent; *5*—massive casing; *6*—liquid in a rubber bag

steps. First, two circular stiffening ribs are stamped in a flat blank for increasing stability of the latter in drawing. The stiffening ribs are so calculated that they straighten in the second step when a given area contacts the punch; otherwise, an irregular surface area will be left on the workpiece.

In *drawing with preventive bending* of the blank, the punch presses the latter in the zone of possible formation of wrinkles. The punch concave edges serve as drawing ribs in further formation of the workpiece.

Rubber-pad drawing is performed either with a rubber pad (punch) and a rigid die, or with a rigid punch and a rubber die (Fig. 48*a*). Both methods are used for making hollow parts from thin sheets. The rubber pad is accommodated in a metal holder. Tools used for rubber-pad drawing are simple since only one deforming element is required—a punch or a die, the other being replaced by a rubber pad.

The pressure of the rubber required for drawing depends on the relative thickness of the blank, Δ, and the draw-reduction ratio.

For instance, in drawing duralumin with $R_{dr} = 0.50$ and $\Delta = 0.4$, the maximum pressure of the rubber is 380 kgf/cm² (38 MPa).

The high specific pressure required and rapid wear of the rubber pad restrict the use of this method.

In *hydraulic drawing* (hydroforming), hollow cylindrical, conical, spherical parts, etc. are obtained by applying pressure of a liquid either directly to a blank or through an elastic (rubber) casing

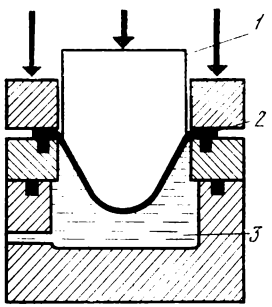


Fig. 49. Diagram of hydromechanical drawing
1—punch; *2*—blank; *3*—liquid die

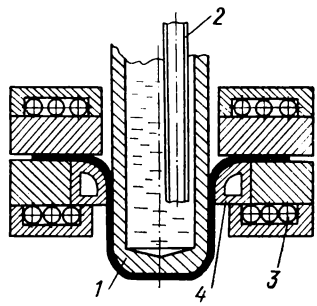


Fig. 50. Drawing with heating of a flange and cooling of a punch and die
1—punch; *2*—tube for feeding coolant; *3*—heating elements; *4*—die with a cooling passage

(Fig. 48*b*). This method is especially effective in making intricate components since it eliminates the use of a metal punch or fitting the latter to the die, thus cutting down the cost of production as compared with conventional drawing in metal tools. The shortcoming of hydraulic drawing is considerable thinning of some parts of the workpiece.

Die *3* (Fig. 48*b*) is made from pig iron, lead-zinc alloys, wood-and-adhesive composition or cement.

In *hydromechanical drawing*, blank *2* (Fig. 49) receives the shape of punch *1* by deforming in liquid die *3*. As the punch moves forward, the liquid pressure forces the blank to the punch thus imparting the required shape and dimensions to the former.

Drawing with flange heating and cooling of the drawn part of the workpiece (Fig. 50) is used for making hollow components from aluminium and copper alloys and from steel. When the flange is heated, the resistance of the metal to deformation decreases. This makes it possible to increase the degree of deformation per draw. Local heating of blanks is also used to reduce local deformation in some other pressworking operations, e.g. bulging. The press tools for drawing with flange heating are provided with means for cooling the bottom and walls of the workpiece being drawn.

Stretch forming is used primarily for making large-size simple thin-walled components, for example, small batches of facing parts for buses, trolleybuses, automobiles. Stretch forming is performed on special hydraulic stretching presses. The blank edges are gripped by press jaws and the blank is stretched over a punch (block) having the shape of the part. This method is employed for working low-carbon and stainless steels up to 1.5 mm thick and aluminium and magnesium alloys, up to 3.5 mm thick. Stretch forming is performed either by moving the bed and block with the jaws stationary (Fig. 51*a*), or by moving the jaws with the block fixed (Fig. 51*b*).

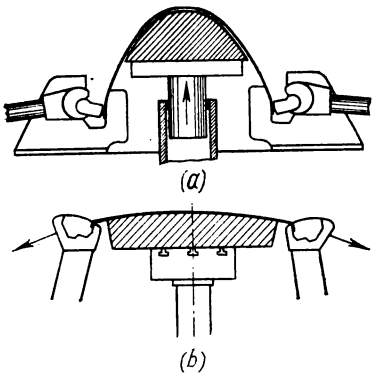


Fig. 51. Stretch forming with stationary jaws (*a*) and with movable jaws (*b*)

Thinning of the metal averages from 5 to 7 per cent. To decrease friction, the block surface should be carefully finished and lubricated.

Pulse forming. Stamping (drawing, blanking, bending, punching, etc.) is performed under the action of an instantaneous pressure pulse produced by explosion (explosive forming), electric discharge in a liquid medium (electrohydraulic forming), or by magnetic field

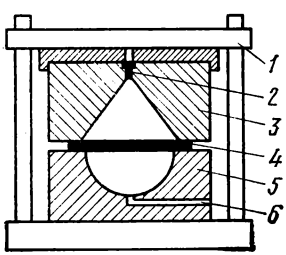


Fig. 52. Diagram of explosive forming
1—frame; *2*—explosive charge; *3*—explosion chamber body; *4*—blank; *5*—die; *6*—vacuumizing passage

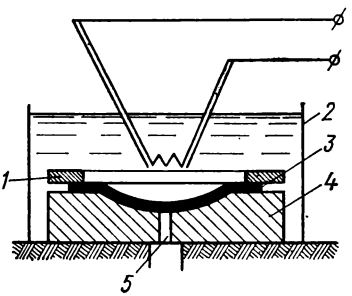


Fig. 53. Electric discharge forming
1—blankholder; *2*—tank; *3*—deformed blank; *4*—die; *5*—vacuumizing passage

(electromagnetic forming). Explosive forming is effected by a shock wave in a gaseous (Fig. 52), liquid (Fig. 53) or loose medium.

In liquid medium explosive forming as well as in electrohydraulic forming, the die is placed in a special tank filled with water. The explosion or electric pulse (Fig. 53) is produced in the liquid medium and the resulting shock wave forms the workpiece. The devices for

explosive forming are arranged in concrete chambers or wells to ensure the adequate safety, and air is evacuated from the die cavity under the blank.

Special guns are also used for piercing. The gun is charged with a cartridge and gases produced in the combustion of the cartridge powder push a special insert carrying the punch which pierces the hole.

In magnetic-pulse forming (Fig. 54), the metal is deformed owing to the interaction of a magnetic field and eddy currents created in the blank when it is cut by the magnetic lines of force. The blank is deformed without the use of punches or any pressure-transmitting media (liquid, gas, sand, etc.), which provides for stamping intricate components from polished blanks or blanks with special platings and also performing assembly operations.

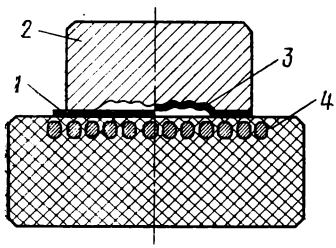


Fig. 54. Magnetic pulse forming
1—initial blank; *2*—die; *3*—deformed blank; *4*—electromagnet

Pulse forming allows working of large-size thick blanks without employing bulky equipment or intricate tooling.

Flanging (Fig. 34*c*) is an operation of making flanges along the outer or inner contour (hole edges) of the blank.

The maximum value of the flange around a hole is indicated by flanging coefficient C_f which is equal to the ratio between diameter d of the pierced hole and that of the flanged hole, D, i.e.

$$C_f = d/D$$

The value of C_f depends on the kind and properties of the material and the ratio between the blank thickness t and the diameter of the pierced hole, d ($\Delta = (t/d) \times 100$). For steel with a carbon content of 0.1 per cent and Δ from 3 to 9, $C_f = 0.60\text{-}0.45$, and with Δ from 67 to 100, $C_f = 0.23\text{-}0.20$.

Flanging is performed in press tools on presses. Punches used for flanging may be cylindrical, tapered or hemispherical. On some occasions flanging is combined with piercing.

The flanging force F with a metal thickness t and a cylindrical punch can be approximately derived from the formula

$$F = 1.5\pi (D - d) t\sigma_u$$

Inward and outward flanging can be combined in one operation.

Embossing is an operation used to obtain small depressions and protrusions, e.g. stiffening ribs, at the expense of local extension and thinning of the material (Fig. 34*h*). Embossing can be performed

separately or in combination with blanking, drawing and the like on friction, hydraulic and crank presses. Sometimes rubber pads are employed for embossing. Thread on hollow sheet workpieces, e.g.

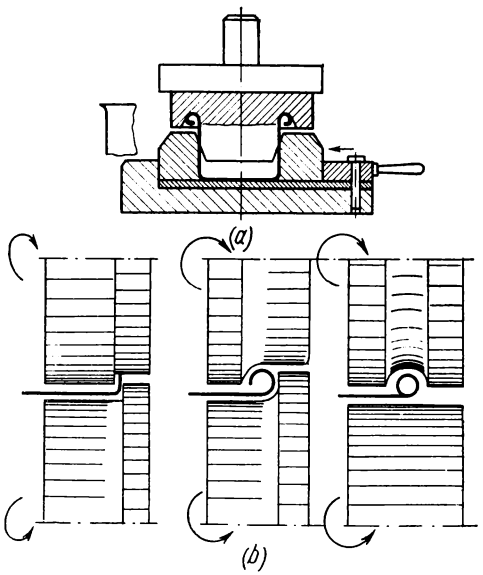


Fig. 55. Beading
(*a*) in a press tool; (*b*) with rolls

electric bulb holders, and various profiles are formed with shaped rollers on thread-rolling machines. To obtain a profiled part, the blank is passed through several pairs of shaped rolls.

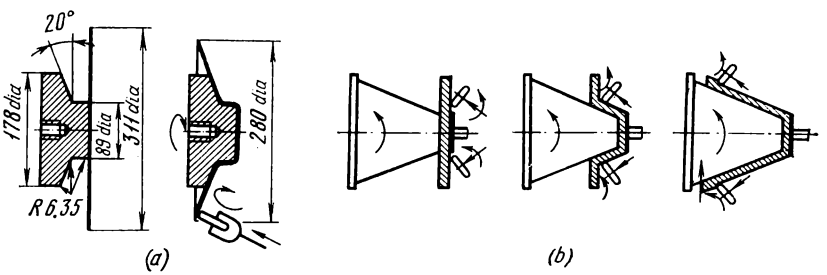


Fig. 56. Spinning
(*a*) without thinning; (*b*) with thinning

Beading is used for rounding off edges of a flat or hollow blank and is performed in tools on presses or with the aid of rolls (Fig. 55*a*, *b*).

Sheet metal solids of rotation can be made by *spinning*. The blank is formed by pressing with rolls to a rotating form block. Spinning

can be performed both with and without thinning of the deformed material (Fig. 56*a*, *b*).

Bulging (Fig. 34*f*) is intended to increase the cross section of a hollow blank, and reduction, to decrease it (Fig. 34*g*). Reduction is used for making necks of pipes or caps. In some cases a form block is inserted inside the blank. The operation performed without such a form block is known as free reduction.

Coining is used to form relief imprints by redistributing the blank metal and filling the press tool coining cavity with it (Fig. 34*j*).

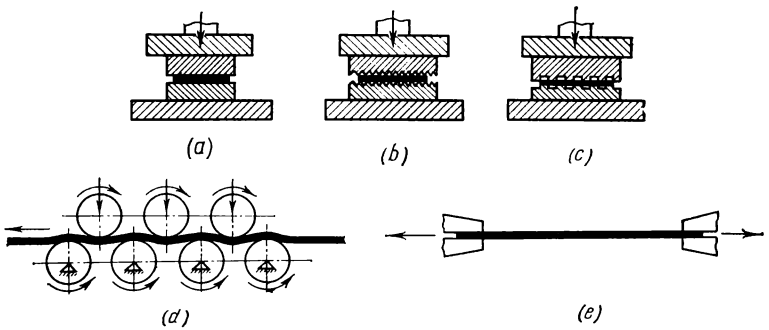


Fig. 57. Straightening methods
(*a*) with smooth plates; (*b*) with pointed plates; (*c*) with waffled plates; (*d*) in rolls; (*e*) by stretching

Dotting is an operation of making dots on the blank surface (Fig. 34*l*).

Straightening is used for eliminating blank shape distortions by deforming the material (Fig. 34*i*).

Straightening serves to correct defects of blanking, punching, etc. When combined with sizing, it rectifies faults of bending and other forming operations.

Straightening is performed in press tools with smooth, pointed or waffled plates (Fig. 57*a*, *b*, *c*). The distance between the teeth of the pointed die is taken approximately equal to the thickness of the material.

A workpiece straightened in smooth plates receives a good surface finish. Pointed or waffled plates are used for works whose surfaces may have slight dents. The straightening force F is found from the formula

$$F = pA$$

where A is the workpiece surface area, mm^2 (m^2), p is the pressure, kgf/mm^2 (MPa), which should be taken from a reference book.

Straightening can be also performed in multi-roll straightening machines (Fig. 57*d*) or by plastic extension by 3-5 per cent (Fig. 57*e*).

Roll straightening is effected by multiple bending of the sheet passed through the rolls.

To make small batches or single parts, drop hammer stamping is used. Such a method which does not require expensive set-ups provides for making parts from aluminium and its alloys, 3 to 5 mm thick, and from steel, up to 1.5 mm thick. Stamping is carried out with a rubber pad and with or without plywood frame plates. If the plywood plates are used, they are so arranged as to limit the depth of drawing. A part of the plates is removed after each blow, thus reaching gradually the desired depth of drawing.

In the case of non-metallic materials, forming operations are usually performed with heating of blanks. For instance, thin-sheet fabric-based laminate is heated to 150-170°C, organic glass—to 105-150°C (for bending) with subsequent cooling of the outer layers for 10-15 s. Organic glass is bent on punches faced with soft sheet rubber or felt.

Vinyl plastic is heated to 160-170°C for bending, and celluloid, to 90-100°C. Flexible micanite can be bent without heating.

Large-size components can be drawn from organic glass in vacuum installations. The blank is heated to 115-120°C either beforehand or directly in the installation. Drawing is performed under the action of the atmospheric pressure by creating vacuum under the blank the edges of which are clamped. Fabric-based laminate heated to 130-170°C is drawn on presses with a blankholder, vinyl plastic and celluloid, in moulds.

4. Combined Operations

Combined operations comprise two or more simple ones (e.g. blanking and punching, punching and bending, etc.). The simple operations included in the combined ones are regarded as steps. In combined stamping separate steps can be performed in succession (in progressive tools) or simultaneously (in compound tools).

With progressive tools, the workpiece is produced by gradually moving a strip, band or individual blank from one position of the tool to the next one after each step. During each stroke of the press in such a tool several different cutting or forming steps are performed simultaneously.

In compound tools, a stamping is made by each stroke of the press without changing the blank position. Such tools perform blanking, punching and drawing; bending and punching, etc. at one station. Compound tools considerably increase the productivity of pressworking.

5. Assembling Operations

In radio engineering, instrument making, consumer goods production and other branches of industry, assembling operations are often

used to connect flat parts by lug bending, seaming, flanging, riveting, forcing, etc. (Fig. 58*a* to *h*).

Stampings made from the same metal or alloy can also be connected by cold pressure welding. Such welding is performed by pressing the spots to be welded with punches at a force ensuring plastic deformation. Aluminium, copper and brass components can be welded by this technique.

A variety of sheet stampings are connected by arc welding, gas welding is used less frequently. Motor and railway car bodies and

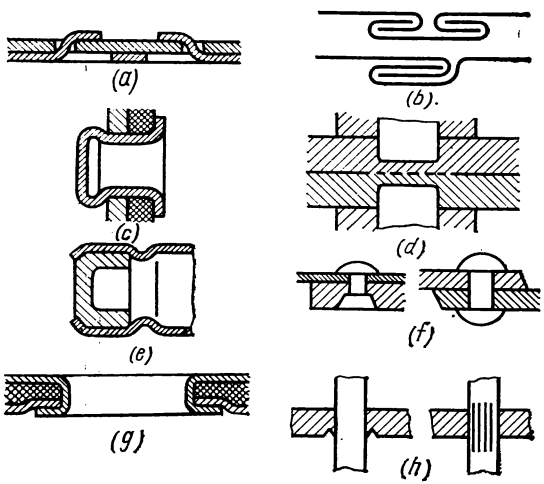


Fig. 58. Assembling operations
(*a*) lug bending; (*b*) seaming; (*c*) upsetting; (*d*) cold welding; (*e*) necking; (*f*) riveting; (*g*) flanging; (*h*) forcing

many consumer goods are made in this way. Owing to their light weight and high strength welded stampings successfully compete with castings and forgings.

Sometimes sheet stampings are jointed by gluing.

Rview Questions

1. Name the principal cutting operations in sheet metal stamping.
2. How are the dimensions of the blank for drawing determined?
3. Describe pulse forming methods.
4. What are combined operations in sheet metal stamping?
5. Describe assembling operations in sheet metal stamping.

Chapter VI

PRINCIPAL OPERATIONS OF COLD DIE FORGING

1. Basic Definitions

Cold die forging is one of the most efficient methods of making parts from steel, non-ferrous metals and their alloys. It is widely employed in mechanical engineering, instrument making and other branches of industry.

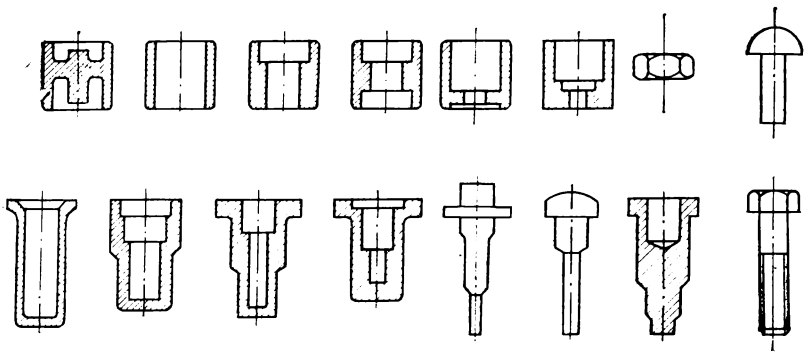


Fig. 59. Sections of semi-finished and finished articles produced by cold die forging

If compared with cutting, cold die forging ensures a higher output, metal economy and improvement of its mechanical properties, increases durability and life of parts.

Cold die forging has a number of advantages over hot die forging. It eliminates the need for heating the metal, removing scale, the metal surface layers are not decarbonized, etc.

Cold die forging considerably decreases scrap, offers accuracy of up to class 3 or 2 (compare with class 7 to 5 in hot die forging), surface finish of class 7 and higher.

Parts produced by cold die forging are often finished on metal-cutting machines (facing, slitting, drilling small holes, etc.).

Cold die forging is widely used for making various standard or unique parts, such as bolts, screws, rivets, antifriction bearing balls, rolls and races, shaped nuts for motor cars, piston pins, small spur and bevel gears, automobile spark plug bodies, watch cases, etc. (Fig. 59).

Die forgings can be connected by welding.

Die forgings are usually produced from cold-drawn stock.

Various steels, and also deformable non-ferrous metals and alloys, such as brasses, aluminium alloys, can be worked by cold die forging.

Cold die forging comprises cutting and forming operations.

2. Cutting Operations

The cutting operations include shearing, trimming and punching.

Shearing (Fig. 60) is cutting of bars into measured length blanks. It is performed on billet and bar shears, shearing presses, ordinary presses with shearing tools or on special automatic presses. The length of the cut off blank, as a rule, must be not less than about half the bar diameter.

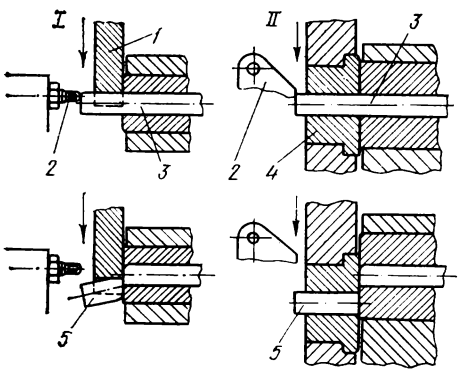


Fig. 60. Blank shearing
I—with a blade; *II*—with a bush-type blade; *1*—blade; *2*—stop; *3*—bar; *4*—bush-type blade; *5*—cut off blank

Cut off blanks have a skew cut and a somewhat distorted shape, while long blanks are slightly bent. When bush-type blades are used, these faults are less pronounced. Proper selection of the angle of tilt of the bar and the same angle of bevel of the blade improves the accuracy of shearing. These angles are 3-7° for steels and are linked with the deviation of the shearing cracks from the force direction in shearing.

The shearing force can be approximately calculated from the formula

$$F = C\tau_{sh}A$$

where C is a coefficient equal to 1.2-1.3, τ_{sh} is the shear strength, MPA (kgf/mm^2), A is the area of the cut surface, m^2 (mm^2).

Cold die forging is performed with or without *scrap* (flash), which is the excessive material that flows from the working space of the tool and has to be trimmed.

To work without flash, the blanks must be sufficiently accurate in volume and weight. Excessive material may cause breakage of the tool or press, while shortage of it, incomplete filling of the die volume.

If pressworking is performed on automatic presses, blank shearing is usually the first step of the cold die forging operation.

Trimming (Fig. 61*a*) is used for separating scrap from the forging and is performed in press tools. The trimming force is determined

from the same formulas as the shearing force. If the cut surface finish is to meet high requirements, shaving or sizing is used.

Punching (Fig. 61*b*) is intended for making small-depth through holes or removing the scrap (film or web) from the hole.

In cold die forging, holes, e.g. in nuts, are usually made in several steps: first depressions are pressed coaxially on both sides of the blank, then the film (web) remaining between the two depressions

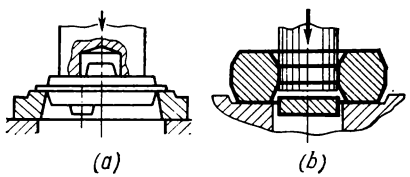


Fig. 61. Cutting operations
(*a*) trimming; (*b*) punching

is removed by punching. The punching force is approximately determined from the same formula as the shearing force.

Plate blanking is used to provide thin blanks for embossing or other forming operations in cold die forging. This operation is described in Chapter V.

3. Forming Operations

Forming operations include upsetting, heading, cavity extrusion, sizing, coining, etc. (Fig. 62*a-i*). These operations are carried out on multi-purpose and special crank or hydraulic presses and various automatic machines.

In *upsetting* (Fig. 62*a*, *b*), the workpiece is shaped by reducing the blank height with a simultaneous increase of its cross section area.

The force required for upsetting is approximately found from the formula

$$F = pA$$

where p is the pressure selected from the reference tables, depending on the ratio between the blank diameter and its height and the degree of deformation, MPa (kgf/mm^2), A is the area of projection of the workpiece onto the plane perpendicular to the direction of punch travel, m^2 (mm^2).

Upsetting is combined with other forming operations or is used for preliminary deforming of blanks (Fig. 63). Such a preliminary deforming eliminates blank defects after shearing, while the use of blanks accurate in shape and dimensions creates favourable conditions for subsequent forging and prolongs the life of press tools.

Heading (Fig. 62*e*) is a kind of upsetting in which only a portion of a blank length is deformed. This operation is aimed at obtaining local thickening and is widely used for making heads of bolts, screws,

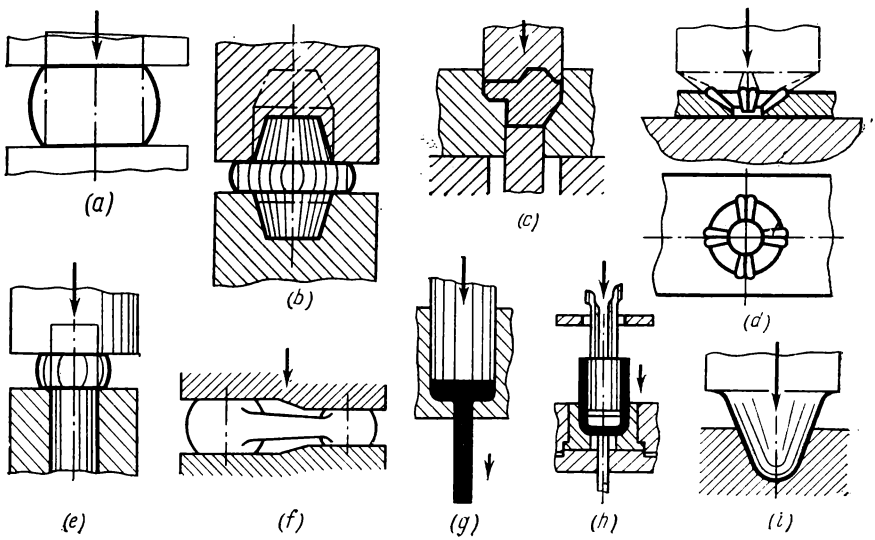


Fig. 62. Forming operations
(*a*, *b*) open upsetting; (*c*) closed upsetting; (*d*) coining; (*e*) heading; (*f*) sizing; (g) forward extrusion; (*h*) backward extrusion; (*i*) cavity extrusion

rivets on automatic heading machines. The capacity of such machines is several hundreds of parts per minute which tens times as high as the capacity of automatic lathes.

The number of blows required for heading is determined from the ratio between length l of the portion to be upset and diameter d

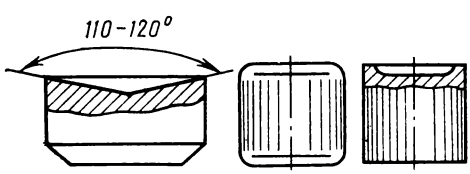


Fig. 63. Blanks after preliminary deformation

of the stock. Meant by length l of the bar is the length of its free portion (Fig. 64). With the volume V of the head to be upset and the blank cross section area A being known, it is possible to determine $l = V/A$.

One blow without a longitudinal bend of the blank can upset a head with the l/d ratio of not above 2.25; two blows, with the l/d

ratio of up to 4.5. Depending on the required number of blows, use is made of one-, two-, three- and four-blow automatic heading machines. With higher l/d values, heading is performed in punches with a tapered cavity. In free heading, surface defects of the material (e.g. haircracks) rapidly manifest themselves on the outer surface of the head. Therefore the head diameter D in free heading is taken up to 2 or 2.5 diameters of the blank, in partially or fully closed heading, up to 3 diameters.

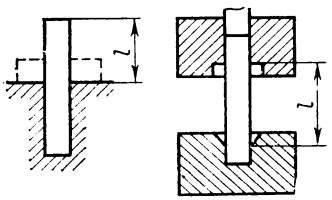


Fig. 64. Diagrams for determining the length of the blank portion to be headed

High efficiency reached in the manufacture of fasteners, various parts with steps, collars and the like by cold heading promotes wide-scale implementation of the automatic cold heading machines.

Extrusion. In this operation the metal being deformed is forced into the opening of the die or through the gap between the punch and the die.

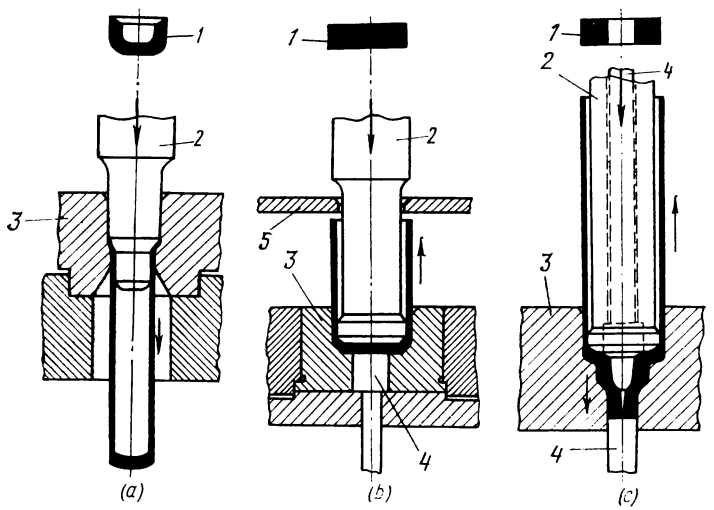


Fig. 65. Cold extrusion
(*a*) forward extrusion; (*b*) backward extrusion; (c) combined; *1*—blank; *2*—punch; *3*—die; *4*—knock-out; *5*—stripper (the arrows show the direction of metal flow)

There are forward (direct), backward, combined and radial methods of extrusion (Figs. 65, 66). In forward extrusion, the metal flows in the direction of the punch working stroke and is forced into the

through opening of the die. Forward extrusion is used for producing both solid (Fig. 62*g*) and hollow (Fig. 65*a*) parts.

In backward extrusion the metal flows in the direction opposite to the motion of the punch and is forced into the gap between the punch and the die (Fig. 65*b*). In combined extrusion, the metal flows in both directions (Fig. 65*c*).

Cold extrusion is used for producing hollow thin- and thick-walled parts with or without projections and lugs, and also various shaped

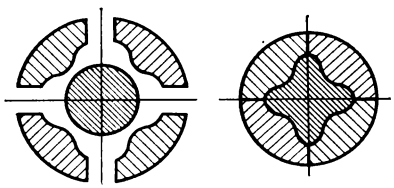


Fig. 66. Radial extrusion

components. The products may be of a square, round, rectangular or other cross section.

The degree of deformation ε in extrusion is determined from the formula

$$\varepsilon = \left(1 - \frac{A_w}{A_{bl}}\right) \times 100\%$$

where A_w is the workpiece cross section area, m^2 (mm^2), and A_{bl} is the blank cross section area, m^2 (mm^2).

Maximum permissible degrees of deformation for various materials are given in reference books. For instance, maximum ε in forward extrusion of aluminium A0, A1, A2 is 98%; in backward extrusion, 96%; for copper M1, M2, M3, the values are 90 and 85% respectively; for brass Л68 and Л62, 85 and 80%.

Forward extrusion with low degrees of deformation (up to 30%) is frequently termed *reducing*.

The extrusion force magnitude is influenced by a plurality of factors, such as the mechanical properties of the blank material, the degree of deformation, the method of extrusion, the condition of blank surfaces, the tool geometry, lubrication, etc.

To manufacture reamers, counterbores and some other tools and symmetrical solid parts, use is made of *radial extrusion* (Fig. 66). In this method the blanks are deformed by forcing in special dies which are moved from the periphery to the centreline of the blank.

Proper preparation of blanks and selection of lubricant are frequently critical for normal flow of the extrusion process.

When extruding aluminium, use is generally made of 20-per cent solution of animal fat in benzene or a mixture of cylinder oil with wax; copper and brass are worked with animal fat and graphite

grease; zinc, with animal fat, lanoline and talc. In extrusion of steel, the blanks are subjected to preliminary phosphotizing followed by coating with metal working soap.

The extrusion force can be approximately calculated as the product of pressure p by the blank cross section area. The approximate values of p, kgf/mm^2, are given in Table 2. Cavity extrusion (Fig. 62*i*) is used primarily in the manufacture of moulds and press tool dies, when a precision and high finish shaped cavity is to be produced in a bulky blank.

Table 2

Approximate Values of Cold Extrusion Pressure p, kgf/mm^2

Materials	Forward extrusion	Backward extrusion
Aluminium	40-70	80-120
Copper	60-100	150-200
Brass Л68	80-150	180-250
Steel 10-15	100-180	200-300

The extruded dies offer higher wear resistance than those produced by machining, with the labour consumption for their manufacture being several tens of times as low.

The extruded parts may reach the accuracy of class 8 or 7 and the surface finish of class 9. Extrusion of cavities is usually performed on hydraulic presses.

Sizing is used to obtain accurate dimensions and high surface finish. As a rule, it is a finishing operation (Fig. 62*f*) in press-working of metals, when a workpiece made by cold or hot die forging must meet high accuracy and surface finish requirements. For instance, cold sizing is used for forged connecting rods of motor car engines, various stamped levers, cold forgings for automobiles, instruments, timepieces, etc.

The sizing force is found from the formula

$$F = pA$$

where p is the pressure, MPa (kgf/mm^2), which is taken from the pertinent reference book, and A is the area of the surface being sized, m^2 (mm^2).

Sizing is performed in press tools of crank, coining and hydraulic presses.

Coining (Fig. 62*d*) is used to form accurate protrusions, depression, inscriptions, patterns, etc., on the surface of the work. It is employed in the production of small parts (e.g. for watches), coins,

medals, badges, etc. The embossed surface is obtained by redistribution of the material which under the action of great forces fills the working cavities of the tool. The coining force is determined from the formula used for calculating the force of sizing. In coining of the brass faces of timepieces and stainless steel articles, pressure p reaches 2 500-3 000 MPa or 250-300 kgf/m^2.

The approximate values of cold extrusion pressure p, kgf/mm^2, are given in the table below.

Coining is mainly performed in closed press tools on coining presses.

Review Questions

1. Name the cutting operations of cold die forging.
2. Draw the diagrams of the forward and backward extrusion methods.
3. Give examples of components obtained by extrusion.

Chapter VII

PRESS TOOLS

1. Classification

Press tools for the pressworking are classified according to the kind of operation performed, their technological features and versatility.

As regards the kind of operation, there are press tools for cutting (blanking, punching, etc.), forming (drawing, bending, upsetting, etc.) and assembly operations (interconnection of separate parts of an article).

With respect to technological features, there are distinguished simple, compound and progressive tools.

Simple tools (Fig. 67*a*) are intended to perform one or several identical operations during one press slide stroke within one feed of the blank. Such tools are used to carry out only drawing or only bending, or punching one or several holes.

In a compound press tool (Fig. 67*b*) several different operations or steps are accomplished during one stroke of the press, e.g. blanking and drawing, bending and punching. Progressive tools (Fig. 67*c*) are designed to perform several operations or steps during several strokes of the press slide. Each pressworking step is effected at a separate station of the press tool and the blank or strip is progressively moved from one station to another after each stroke. The progres-

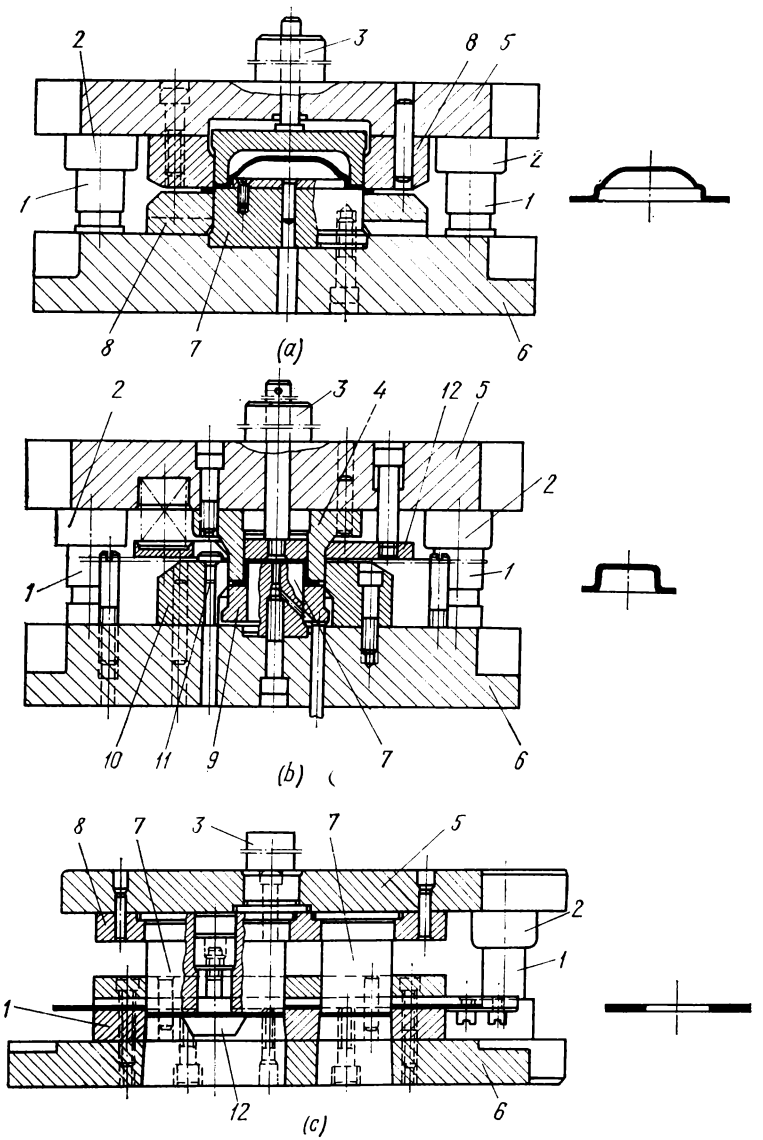


Fig. 67. Press tools

(*a*) simple for trimming shell; (*b*) compound for blanking disk and drawing cap; (*c*) progressive for blanking washer and punching hole in it; *1*—guide posts; *2*—bushings; *3*—shank; *4*, *10*—dies; *5*—punch holder; *6*—die shoe; *7*—punch; *8*—punch plate; *9*—blankholder; *11*—stop; *12*—stripper

sive tools may include the features of compound tools, i.e. several operations can be accomplished at a separate station.

Simple press tools are elemental in design and inexpensive. They are frequently used in batch and small-batch production. Compound

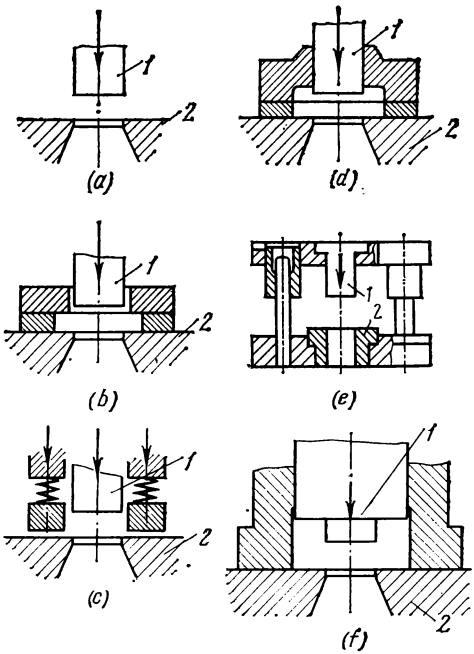


Fig. 58. Press tool types
open: (*a*) without guides; (*e*) with guide posts; closed: (*b*) with a fixed stripper; (*c*) with a movable stripper; (*d*) with a guide plate; (*f*) with a guide plunger; *1*—punch; *2*—die

and progressive tools are more intricate in design and more expensive, but their output is higher. They are used mainly in large-batch and mass production.

In mass pressworking on multi-station automatic presses, simple tools individual for each pressworking station are usually employed.

As regards versatility, press tools can be special- or multi-purpose. Special-purpose tools are used for making one particular component. Such a tool is made of subassemblies and parts intended solely for this particular tool. A multi-purpose tool can be adapted for manufacturing different components by resetting or replacing its separate sudassemblies (assemblies). Multi-purpose tools include resettable press tools, insert press tools, press tools with a replaceable set (punch and die) and sectional tools.

In a resettable press tool, versatility is achieved by resetting the tool parts relative to each other. Sectional tools are assembled from a universal set of parts and subassemblies (assemblies) intended for multiple re-use.

By design, press tools can be without or with guides which ensure accurate alignment of the punch and die in pressworking.

Press tool guiding devices include guide posts (Fig. 68*e*), guide plates (Fig. 68*d*) or a guide plunger (Fig. 68*f*).

Press tools with free access to the die space are called *open* (Fig. 68*a*, *e*), those in which this space is closed are called *closed* (Fig. 68*b*, *c*, *d*, *f*). Both open and closed tools can be without or with guides. Closed tools ensure that the operator's hands never get into the zone between the punch and die, and therefore, they are safer in operation. When open tools are used, various protective devices are installed to preclude injury to the operator's hands.

Depending on the construction of a stripper, there are tools with a fixed stripper and with a movable one which can be either rigid with rods or a spring-loaded one.

By operation features, press tools are distinguished according to the method of feeding the stock or blanks, removing finished parts and ejecting the scrap. These operations can be performed either manually or automatically with the use of special devices.

The construction of press tools should comply with safety standards.

2. Press Tool Components

As regards their purpose, the press tool components are divided into technological and structural ones. The former directly ensure the accomplishment of an operation and interact with the material

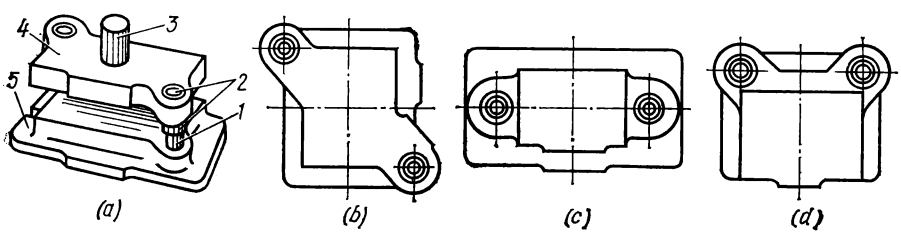


Fig. 69. Die set (*a*) and types of sets depending on the location of guiding parts (units)
(*b*) with diagonal arrangement; (*c*) with axial arrangement; (*d*) with rear arrangement; *1*—guide post; *2*—bushing; *3*—shank; *4*—punch holder; *5*—die shoe

being worked. They include punches, dies, guides, blankholders, knock-outs, etc. The latter serve for integrating all the components into a sturdy structure and securing the tool on the press. These include punch holders and die shoes, shanks, guide posts, fasteners.

Press tools regularly consist of a die set, which is a set of structural parts (Fig. 69*a* to *d*) and several technological subassemblies (assemblies).

A die set comprises a punch holder and a die shoe, guiding devices (usually a post and a bush) and a shank.

By versatility, there are special and general-purpose sets. The former are intended for use with a permanent insert set, the latter, with a replaceable insert set. An insert set is a set of parts mounted in a die set to ensure accomplishment of a given operation.

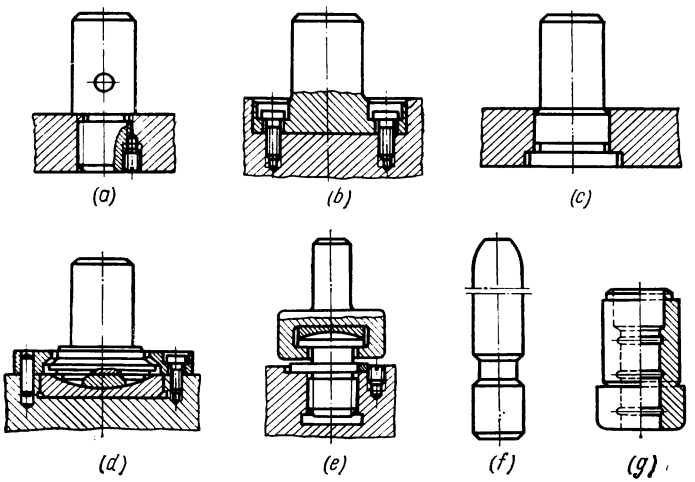


Fig. 70. Die set components
types of shanks: (*a*) with a threaded end; (*b*) with a flange; (*c*) forced-in with a collar; (*d*) floating; (*e*) floating for precision press tools; (*f*) guide post; (g) bushing

Press tools are made mainly from standard components. There are specifications and standards for punch holders and die shoes, shanks, punches, dies, and many other parts of press tools.

Punch holders and die shoes (Fig. 69*a*). These carry all the components of a press tool. The shape and size of punch holders and die shoes are selected to suit the size of the stampings, the types of press-working steps, the dimensions of the die space of the press, etc. They are cast from iron or steel.

Shanks (Fig. 70*a* to *e*) are used in small and medium-size tools to fasten the punch holder to the slide. These are made from steel grades 45, 50, etc.

Guide posts and bushings (Fig. 70*f*, *g*) ensure accurate alignment of the punch holder with the die shoe, hence of the punch and die in operation. The use of guide posts and bushings simplifies mounting and adjustment of the tool on a press. A tool may be provided with several sets of guide posts and bushings. The guide posts are made with recesses which divide them into two portions. One portion

is forced into the punch holder or die shoe and the other serves to guide the slide motion. The posts are usually forced into the die shoe, while the bushings, into the punch holder. Sometimes, to facilitate removal of the work, the posts are forced into the punch holder and the bushings, into the die shoe. In some tools one of the posts may be forced into the punch holder and the other into the die shoe.

The bushings and sometimes the posts are made with oil grooves. Use is also made of races with balls or rollers which considerably

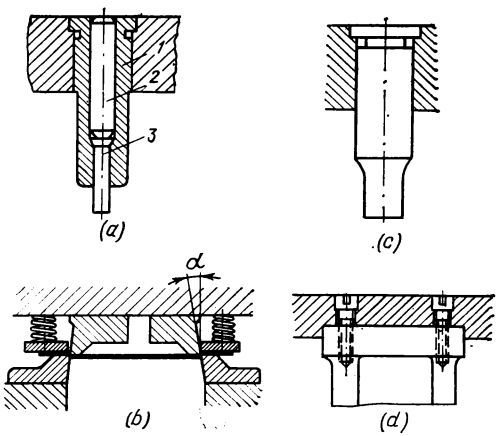


Fig. 71. Punches
(*a*) for small holes; (*b*) sectional punch and die assembly; (*c*) for medium-size holes; (*d*) special blanking punch; *1*—quill; *2*—pin; *3*—punch

decrease friction especially in high-speed pressworking. The posts and bushings are usually made from steel, grade 20, are case-hardened to a depth of 0.5-1.0 mm, then are hardened and tempered to obtain a surface hardness of HRC 58-62. Such posts and bushes have a soft core and hard surface, which gives them high wear resistance and strength. Some posts are made from steel, grade 45, and subjected to hardening.

Punches (Fig. 71*a* to *d*). Punches of different purposes and designs are used in tools for sheet metal pressworking. The geometry of the working part is selected depending on the purpose and shape of the workpiece, while the dimensions are determined by calculations.

Large blanking punches, e.g. those used for blanking the facing components of motor-vehicles are made by casting. Medium-size punches are made from steels У10А, Х12М, 6ХВФ, etc. The punch working surface is hardened to HRC 54-58. The steel grade and working surface hardness are in accordance with the purpose of the punch.

Dies. The design of a die depends on the operation to be accomplished. For blanking small round parts or punching small holes, round dies are used (Fig. 72*a*). One-piece or sectional dies with a shaped hole are designed for blanking shaped parts or punching shaped holes

(Fig. 72*c*, *d*). Separate components of large shaped sectional punches and dies are attached to the respective components of the press tool. Components of small sectional dies are forced into a common holder. Large drawing dies are sometimes made by casting.

Dies are usually manufactured from steel of the same grades as the punches. Parts of sectional dies for blanking small parts are made

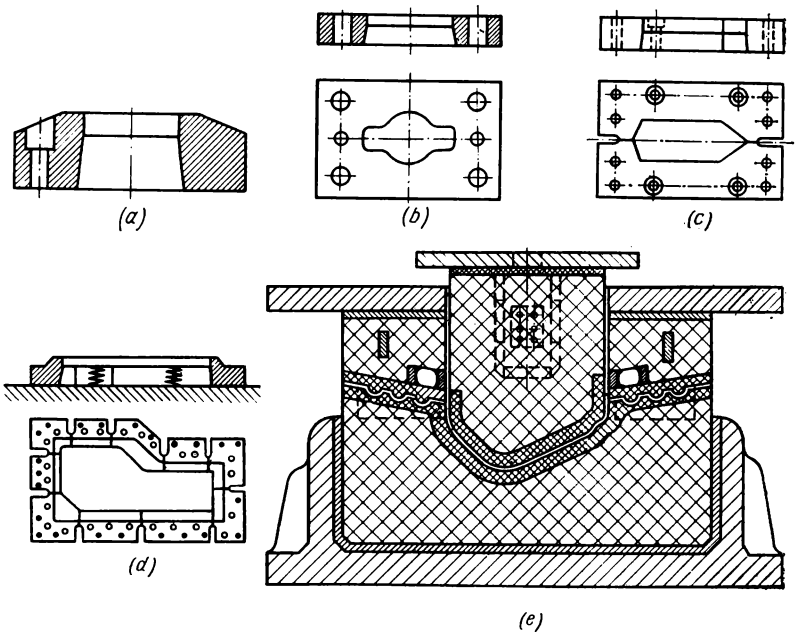


Fig. 72. Dies
(*a*) annular; (*b*) rectangular one-piece; (c) rectangular sectional; (*d*) sectional multi-piece; (*e*) drawing punch and die set made from plastic enclosed in metal casing (blankholder also shown)

from hard alloys. Hardness of heat-treated working surface of steel dies is usually within HRC 56-60. For drawing large components use is also made of plastic dies and punches enclosed in metal casings (Fig. 72*e*). Such press tools are cheaper than metal ones but have a shorter life. For drawing and forming small lots of large and medium-size parts, punches and dies are sometimes cast from low-melting alloys.

Mounting of punches and dies. Punches and dies are generally mounted in their holders and shoes by means of punch and die plates (Fig. 73*a*, *b*, *c*, see also Fig. 67*a*, *b*) or directly (Fig. 74). Small punches are forced in the plates. The punch and die plates are screwed to

the punch holder and die shoe and are fixed by pins. Sometimes a back-up plate made from hardened steel is placed between the punch plate and the punch holder to protect the latter from dents that might be produced by the punch nose during operation of the tool.

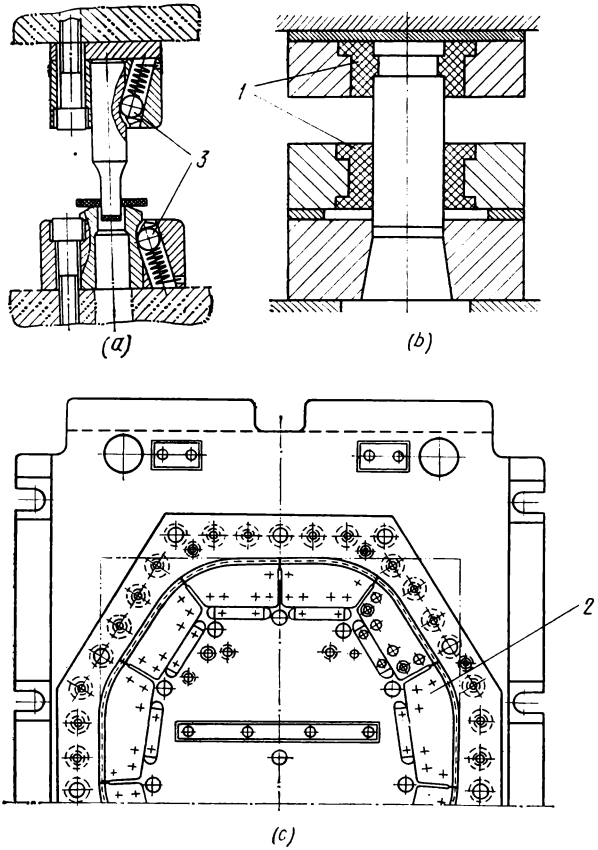


Fig. 73. Mounting of punches and dies
(*a*) quick-change mounting; (*b*) with potting quick-setting plastic in a punch plate and stripper; (*c*) mounting of a sectional punch; *1*—quick-setting plastic; *2*—sections; *3*—ball lock

Small dies can be also forced into blocks which are fastened to the shoe by screws and pins. Large punches and dies can be forced into special borings provided in the punch holders and die shoes (see Fig. 67*a*) or screwed to their ground surface and located by pins (see Fig. 67*b*). If a punch or die is assembled from separate sections (see Fig. 72*d*), each section is located with at least two pins and is fastened with at least two screws.

Besides, to locate punch and die sections, keys are used or the segments are recessed into the punch holders or die shoes.

Quick-change punches and dies can be locked in place by a spring-loaded ball lock (Fig. 73*a*), a nut with an internal conical surface,

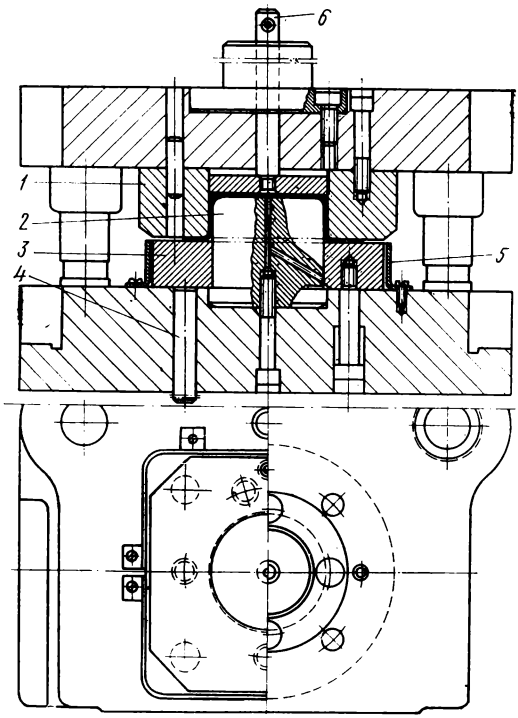


Fig. 74. Direct mounting of punch and die to a punch holder and die shoe

etc. Guide posts and bushings, as well as punches and dies are sometimes secured by potting with low-melting metals or quick-setting plastics (see Fig. 73*b*).

Fixing and guiding parts of press tools are stops, guide pins, pilots, guide planks and side holders, etc. (Fig. 75*a*, *b*, *c*). Stops serve for accurate positioning of sheets, strips, or blanks fed into the tool. The stock bears against the stop and is thus guided in the direction of feed relative to the punch and die. Stops are used only in manual feed pressworking and may be movable or fixed.

Guide pins are used in progressive tools to rectify errors in feeding the stock. A guide pin is usually mounted at the second or one of the following stations of the tool. It enters a previously punched hole and accurately positions the stock in the tool. Pilots arranged on the surface of a die are intended for accurate positioning of separate

blanks relative to the punch and die in two directions. Guide planks and side holders orient the stock in the tool in the lateral direction only (Fig. 75*d*, *e*).

Blankholders, strippers and knock-outs. Blankholders are necessary to prevent wrinkles in drawing. They are also used in blanking and punching to keep a flat work straight and can double as strippers.

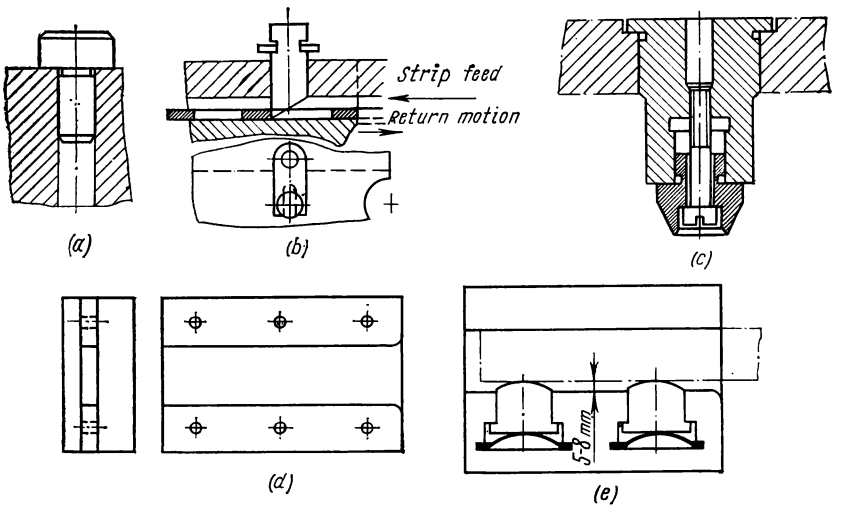


Fig. 75. Press tool positioning and guiding parts
(*a*) fixed stop with a round head; (*b*) a movable spring-loaded return-action stop; (*c*) guide pin; (*d*) guide planks; (*e*) side block-type holder

In blanking and punching, the metal deforms elastically and tightly surrounds the punch. To remove the metal, use is made of fixed or movable strippers. In blanking, punching and drawing, the work or scrap cannot always be removed by pushing it through the die hole. On such occasions backward ejection is carried out by means of knock-outs. These can be of the mechanical (rigid or spring-loaded), hydraulic or pneumatic types.

Various types and designs of guiding, holding and ejecting parts of press tools will be considered later in the book.

3. Tools for Sheet Metal Stamping

Cutting tools. These include tools for blanking, shearing, punching, trimming and shaving and can be simple, combined, or progressive, open or closed, etc.

A *blanking tool* (Fig. 76) has a working zone closed by fixed stripper *10* under which the strip to be blanked is fed. Stripper *10* is

secured to the die shoe with screws *3*. Die *11* is fastened with screws and pins to die shoe *12*. The punch is oriented relative to the die by guide posts *4* and bushings *5*. The moving strip is directed transversely by means of guide bars *2* and laterally, by fixed stop *1*.

The tool works as follows. A strip is introduced into the space between guide bars *2* under fixed stripper *10* and is moved up to fixed stop *1*. Punch *8* mounted in punch plate *6* lowers and cuts out the blank. During its upward movement the punch lifts the strip (scrap) tightly surrounding it until the strip is retained by stripper *10* and removed from the punch. Next the press operator slightly lifts the stock and moves it further up to fixed stop *1* which locates the strip in a new position. The strip travel is equal to one pitch of the stamping operation. The tool has shank *7* secured in punch holder *9*.

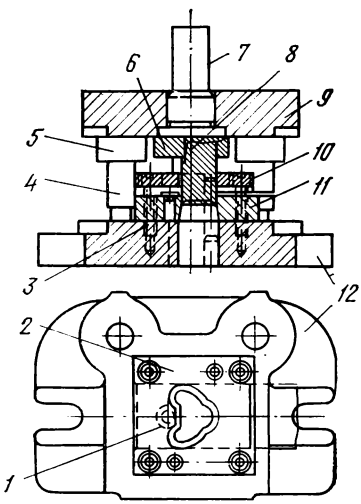


Fig. 76. Closed blanking press tool

In a *tool* (Fig. 77*a*) *for punching shaped holes and side notches in shrouds*, punch holder *4* with flanged shank *3* is oriented with respect to die shoe 6 by means of guide posts *14* and bushings *2*. Shaped punch *10* and side punch *11* are secured in punch plate *5* fastened to the punch holder with screws and pins. Punching die *9* is recessed into die shoe *6* and is secured in place with screws and pins. The blank (Fig. 77*b*) is introduced into the tool between guide bars *8* and *12*. The pitch of feeding is limited by a special stop.

Guide plate *7* presses the blank to the die during stamping thus improving the quality of punching. Plate *7* doubles as a stripper and additionally guides the punches during working stroke. The punches move in the holes of plate *7* with clearances ensuring slide fit of accuracy class 2.

The plate is guided by posts *14* and additional bushings *13*. The guide plate is pressed against the blank by springs *1* fitted on guide posts *14* and resting upon punch holder *4*.

A *compound tool for blanking and punching steel washers* (Fig. 78*a*, *b*) has a die set consisting of punch holder *10* and die shoe *14* aligned relative to each other by means of guide posts *5* and bushings *7*. Shank *9* enters with its flange into a boring in punch holder *10* and is screwed to the latter. The tool has punch *6*, punch-and-die *13* and blanking die *12*. Punch *6* punches a hole in the stock pushing

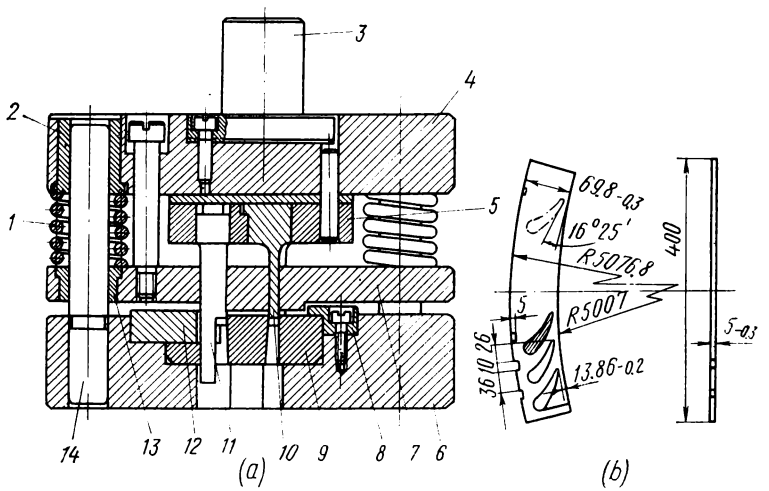


Fig. 77. Press tool for punching shaped holes and side notches (*a*) and sketch of a workpiece (*b*)

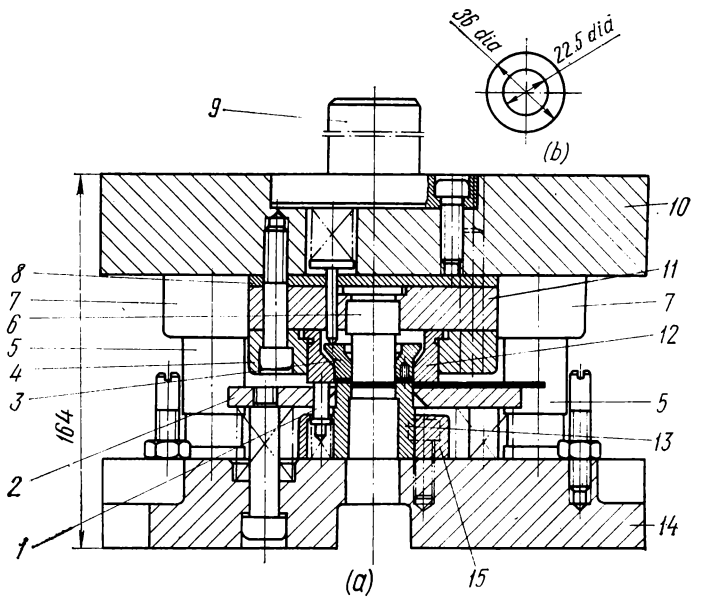


Fig. 78. Compound tool (*a*) for punching a hole and blanking a washer (*b*)

the scrap through a hole in punch-and-die *13*. The latter simultaneously blanks the washer.

The finished washer is ejected from die *12* and is simultaneously removed from punch *6* by spring-loaded knock-out *3*. The strip is removed from punch-and-die *13* by spring-loaded stripper *2*.

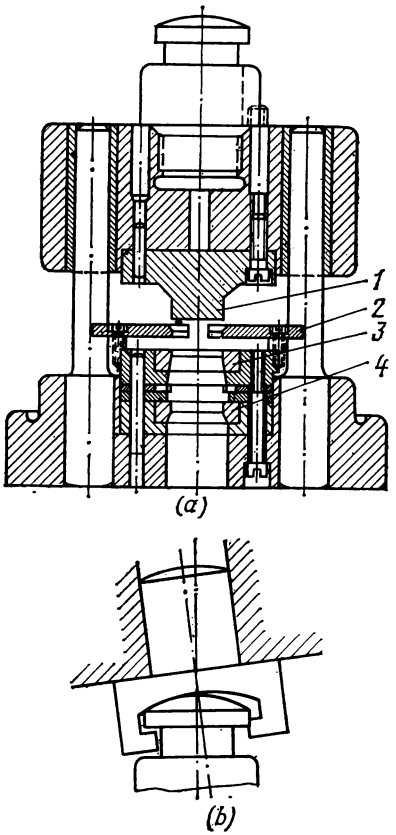


Fig. 79. Shaving tool (*a*) and floating shank diagram (*b*)

The strip feed after each press stroke is limited by spring-loaded stop *1*. Punch-and-die *13* is fastened to the die shoe by means of die plate *15*. Punch *6* is forced into punch plate *11*; the latter and upper die plate *4* are secured to the punch holder with screws and locating pins. Back-up plate *8* is arranged under the punch plate.

Trimming tools are intended to trim off the scrap along the outside contour of a workpiece after forming operations.

These tools are constructionally similar to blanking ones and may be either simple or compound.

Shaving is performed in *shaving tools*. These may have one or several dies arranged consecutively one under another. Fig. 79*a* shows a shaving tool intended for shaving a workpiece consecutively in two dies during one stroke of the slide.

The part to be shaved is placed in nest *2*. Shaving punch *1* pushes the part through shaving dies *3* and *4*. The tool has guide posts and bushings. The punch and the set of dies are mounted in borings of the punch holder and die shoe, and are held in place with screws and locating pins.

This tool has a shank with a spherical head (Fig. 79*b*) which is freely connected to a holder located in a hole in the press slide. Such a connection makes it possible to reduce the influence of slide misalignment on the guide set of the tool, thus ensuring a higher accuracy of work.

A press tool for shearing rectangular blanks from a strip and punching

holes in them is shown in Fig. 80. The strip is fed up to stop *1*, two holes are punched therein by punches *6* and the blank is sheared by

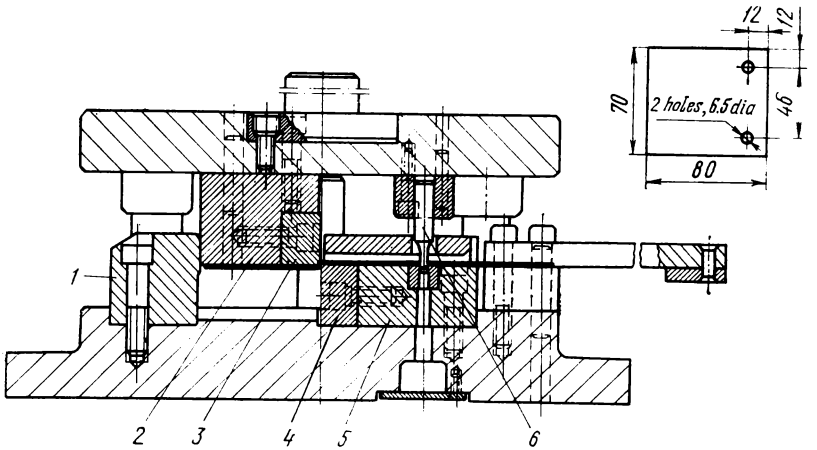


Fig. 80. Progressive tool for punching holes and shearing off strip

cutting-off punch *3* secured to punch plate *2* by means of screws. Second stationary bottom cutter *4* is secured to die plate *5*. The punch has guide posts and bushings, and a flanged shank.

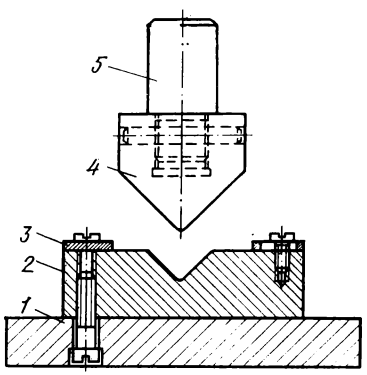


Fig. 81. Simple bending tool

Forming tools. These are divided into bending, drawing, flanging, straightening, embossing, sizing tools, etc., and may be open or closed, simple or combination (progressive and compound). Combination tools combine different forming or forming and cutting operations.

Figure 81 shows a very simple bending tool. Punch *4* is secured directly to shank *5*, while die *2*, to die shoe *1*. The blank is placed on the die between stop bars *3*.

In a *bending tool with guide posts* (Fig. 82) punch *4* is secured to punch holder *3*, while bending die *5* is positioned in a special recess of shoe *6*. The die and punch are secured with screws and locating pins. The blank is fed up to fixed stop *1* and is held in place by spring-loaded stop *2*. After bending, the work is ejected from the tool by knock-out *7*.

More intricate workpieces are made in complex bending tools with rocker arms or blocks, movable wedges, revolving rolls, etc. Such tools are more expensive but reduce the number of bending operations required for making the parts. Therefore, they become economi-

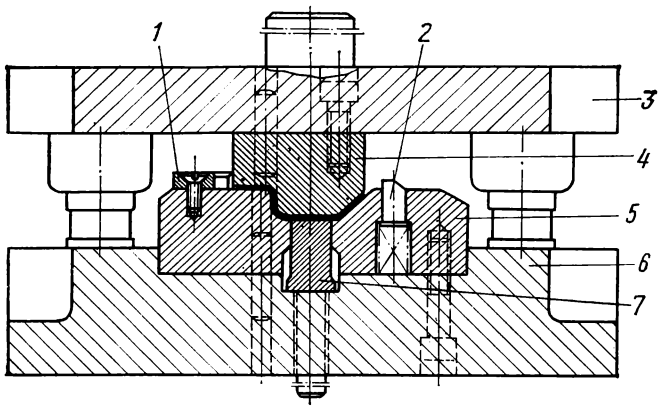


Fig. 82. Open bending tool with guide posts

cally feasible only when sufficiently large quantities of parts are to be produced.

Figure 83 shows a *complex bending tool* for making a T-shaped clamp from a U-shaped blank. Die shoe *1* of this tool carries die plate *2* to which stop bars *7* and insert *3* are screwed. The blank is supported in the insert during bending. When punch holder *4* moves down, punch blocks *6* rocking on pivots *5* slide along stop bars *7*. Bending punches *9* are attached to the blocks. The blank is fitted onto T-shaped core *8* and pressed against it. The finished stamping is removed by shifting along said core. The sequence of tool operations is shown by positions *I*, *II*, *III*, *IV*.

In a *tool for bending a clip* (Fig. 84), the flat blank is bent by rod punch *1* and slide blocks *2* which move toward each other when the punch holder goes down. The slide blocks move as a result of their base surfaces sliding along the inclined surfaces of wedges *3*. The clip is removed from the rod punch after the slide blocks are set apart.

In a *tool for bending rings* (Fig. 85), the flat blank is pressed around rod punch *2* by turning cams *1*.

Drawing tools are used for making various hollow parts, such as cylindrical caps, rectangular boxes, shaped components, etc. The tools for the first drawing operation are designed to be used with flat blanks, while those for the second or subsequent operations, with the semi-finished articles coming from the previous tools.

The drawing tools may or may not be provided with blankholders, which depends on the relative thickness of the blank or workpiece.

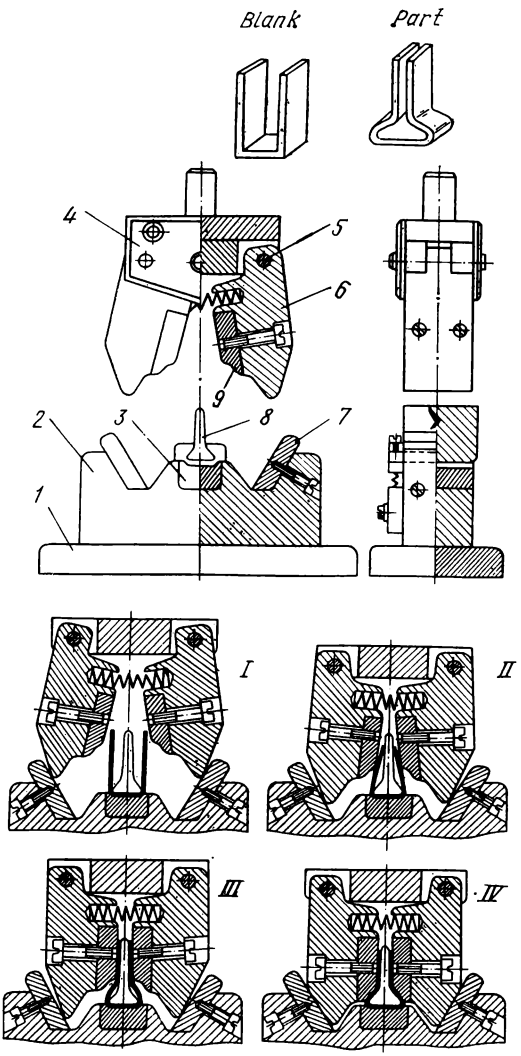


Fig. 83. Tool for bending T-shaped clamp and bending steps (*I-IV*)

Punch *5* of a simple drawing tool without a blankholder (Fig. 86) is attached to shank *3* by means of punch holding ring *4*. Die *6* has pilot *2* for orienting the blank. The die is secured to die shoe *1* which is mounted on the press bed. To facilitate removal of the drawn workpiece and evacuation of air, through holes are made in

the punch and shank. The workpiece is ejected from the punch by three spring-loaded strippers *7* mounted under the die. The strippers remove the workpiece from the punch when the slide moves upwards.

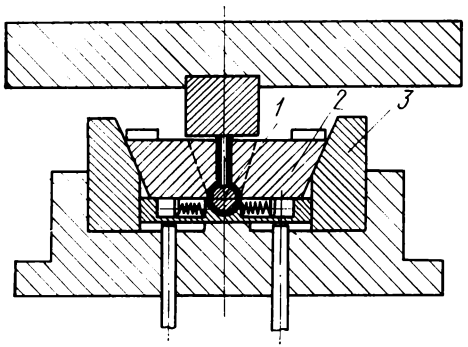


Fig. 84. Tool for bending clips

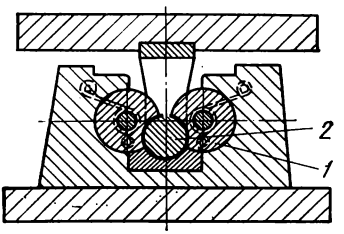


Fig. 85. Tool for bending rings

The inverted drawing tool with guide posts and a blankholder for drawing a cylindrical cap with a flange shown in Fig. 74 has inverted punch *2* installed in a boring in the die shoe and secured with a central screw. The punch has holes allowing air to pass under the workpiece when the latter is being removed. Inverted die *1* is secured to the punch holder by means of screws and locating pins. Annular blankholder *3* is moved by rods *4* operated from a pneumatic ejector (cushion) of the press. The zone of blankholder travel is protected by casing *5*.

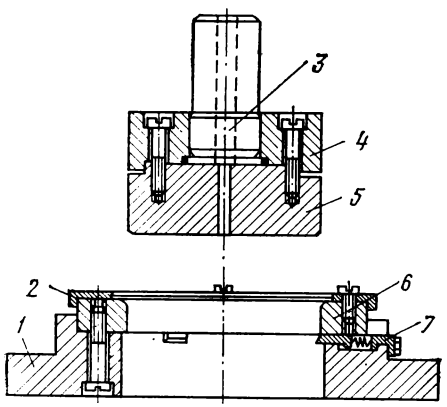


Fig. 86. Simple drawing tool

The drawn cap is removed from the die by upper knockout *6* actuated by the lateral bar of the press slide. At the beginning of the operation a round blank is placed on blankholder *3* and is oriented against the pilot pins. The blankholder is in its upper position so that its upper plane is somewhat above the end face of the punch.

When the upper part of the tool descends, the die first presses the blank against the blankholder and then effects drawing by moving onto the punch. The blankholder moves down with the die.

A *compound tool* (Fig. 67*b*) is intended to blank disks and draw flanged caps from them. Unlike the drawing tool shown in Fig. 74, this one, instead of an ordinary die, has punch-and-die *4* the inside contour of which serves as a die for drawing, while the outside one, as a punch for blanking the disk. Disk blanking die *10* is arranged in a boring in the die shoe. The strip is fed up to stop *11* mounted on the face of die *10*. The scrap is removed from the punch-and-die by spring-loaded stripper *12*.

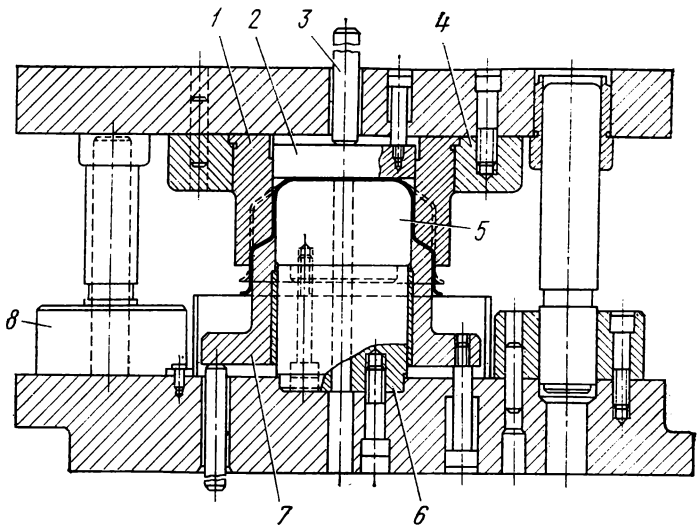


Fig. 87. Tool for second drawing
1—die; *2*—knock-out; *3*—knock-out stud; *4*—die block; *5*—punch; *6*—quill; *7*—blankholder; *8*—tool shutheight limiting post

The above drawing tools are intended for use on single-action presses. The first of them (see Fig. 86) is designed for downward drawing, the other two (Figs. 67*b* and 74), for upward drawing.

If a drawing operation comprises several steps, the workpiece obtained during the preceding drawing step serves as a blank for the succeeding step. For instance, the blank for the fan pulley second drawing tool (Fig. 87) is a predrawn cylindrical cap shown by a dashed line in the figure. This tool is designed for upward drawing.

Drawing, blanking and punching are frequently combined in one press tool. An example is a tool (Fig. 88) for making a fire extinguisher bottom. This tool carries out blanking, drawing and punching. The bottom is made from a strip of steel, grade 08, 1.5 mm thick. The strip is fed into the tool up to stop *5*. Then punch-and-die *2* cuts out a blank which is pressed between the faces of the punch-

and-die and blankholder *3*; punch *4* performs drawing by entering into punch-and-die *2*. Punch *1* makes a hole in the bottom centre and the stamping is removed by blankholder *3*.

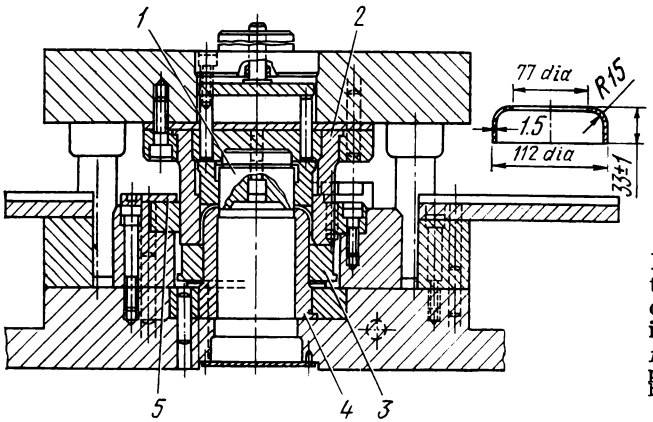


Fig. 88. Compound tool for blanking, drawing and punching

1, *4*—punches; *2*—punch-and-die; *3*—blankholder; *5*—stop

Drawing of large components, e.g. facings of motor vehicles, is performed by cast punches and dies. Punch *1* (Fig. 89) of such a tool for a double-action press is secured to the inside slide either directly or by means of a special plate. Blankholder *2* is attached to the outside slide of the press, while die *4* with associated parts, to the press bed.

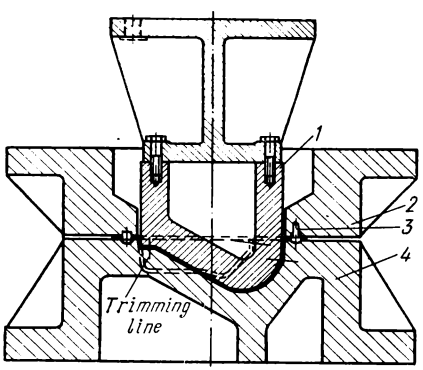


Fig. 89. Drawing tool for a double-action press

Such tools may have drawing ribs *3* arranged on the blankholder-to-die contact surface. Depending on the nature of the drawing operation and subsequent trimming, these ribs may be secured either to the blankholder or to the die. They are intended for applying a backward pressure to the material, which makes it possible to control metal flow and create more favourable conditions for drawing.

Large plate metal components such as bottoms are usually drawn in a hot state on hydraulic presses with the use of special design tools (Fig. 90). Such a tool has annular (often sectional) die *1*, blankholder *2* and sturdy punch *3*.

In the small-batch production of medium- and large-size parts from plate and sheet metal, use can be made of instantaneous pulses formed by explosives, electric discharge in liquid, etc. In this case the tool comprises only a die and a blankholder.

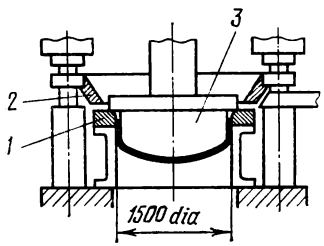


Fig. 90. Tool for drawing large parts of bottom type

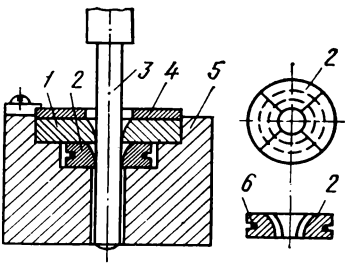


Fig. 91. Ironing tool

Ironing tools (Fig. 91) have elongated punch *3* and one-piece annular die *1* recessed in die shoe *5*. Pilot *4* is placed on the die and the hollow blank is placed in the nest of the pilot. Since ironing is accomplished with a push-through punch, stripper *2* is arranged under the

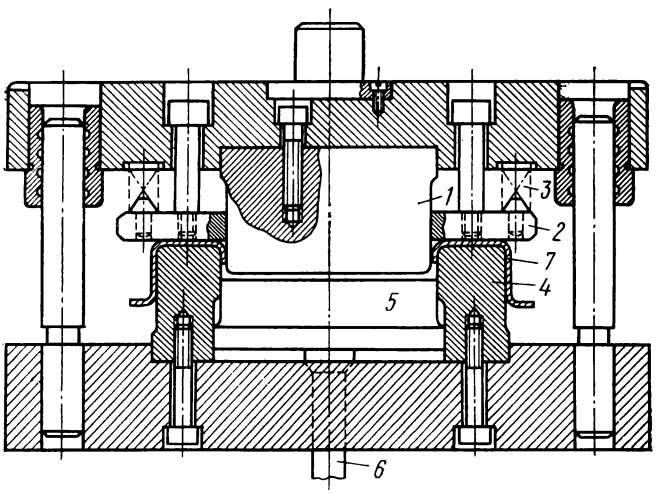


Fig. 92. Flanging tool

die. It comprises four sectors held together by steel spring *6*. The blank drawn through the die moves the sectors apart extending the spring and freely moves downward through the stripper. The

spring returns the sectors towards the centre and the latter tightly grip the punch. During the return stroke of the slide the work bears against the sharp edges of the stripper sectors and separates from the punch. The figure does not show the die set with the guide device.

Flanging tools intended to flange the outer contour or the hole edge are usually manufactured with guide posts and bushings. Fig. 92 shows a flanging tool in which work *7* is pressed against die *4* by blankholder *2* under the action of springs *3*. Flanging is performed by punch *1*. The stamping is ejected by knock-out *5* actuated by pusher *6*.

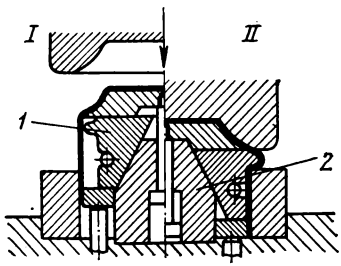


Fig. 93. Bulging tool
I—position before bulging; *II*—position after bulging

Bulging tools may be mechanical, with an elastic working member, such as a rubber punch, and hydraulic. In small-batch production, bulging operations may be performed in special devices using instantaneous powerful pulses.

The mechanical bulging tools can produce the required deformation by the motion of cams *1* (Fig. 93) expanded by means of cone *2* or wedges. In bulging with rubber, local deformation of material is obtained under the pressure of an elastic rubber ring or punch. When a liquid is used, the stock is deformed by its pressure.

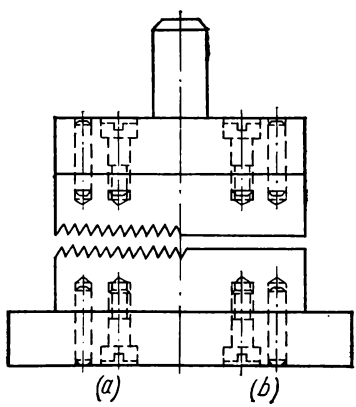


Fig. 94. Straightening tool
(*a*) with indented plates; (*b*) with smooth plates

Tools for straightening flat parts (Fig. 94) have two sturdy plates, one (movable) being attached to the punch holder and the other (stationary), to the die shoe. Such plates may be smooth or corrugated with an indented or waffled surface. Smooth plates (Fig. 94*b*) are mainly used for straightening semi-finished work that is to have a good surface finish. Indented plates (Fig. 94*a*) are so arranged relative to each other that depressions on one plate are opposite to the projections on the other. The indented or waffled plates offer good straightening action but leave indentation on the work surface. Sometimes straightening is combined with local bulging, partial bending and other operations.

Simple and multi-purpose tools. The manufacture of complex tools requires considerable expenditure; therefore they are not econ-

omically feasible for small-batch production and are substituted with simple and multi-purpose tools.

Simple tools include plate tools, tools with rubber deforming members and some others.

If only a few sheet blanks are required, use can be made of a simplest plate punch made from plate tool steel. Blanking is performed

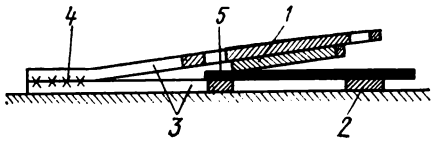


Fig. 95. Pincer-type tool

as follows. Hardened steel plates are secured to the bed and slide of the press. A back-up strip of soft metal (for instance, aluminium) is placed on the lower plate. The blank strip is placed on the back-up strip and the plate punch is positioned on top. When the plate attached to the press slide moves down, the plate punch cuts out blank and forces it into the soft back-up strip.

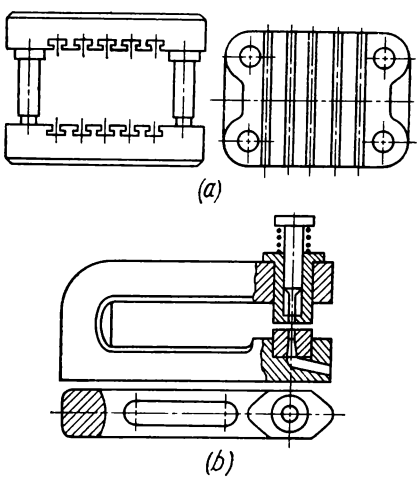


Fig. 96. Die set (*a*) and interchangeable unit (*b*)

After the slide is lifted the blank strip is removed and slightly bent with hands to make the punch drop out. The back-up strip is shifted and the next blanking operation is performed. To remove the blank from the back-up strip, the latter is turned over and also slightly bent. This method is used for cutting out steel blanks from steel up to about 1.5-2 mm thick.

The pincer-type tool shown in Fig. 95 is another example of a plate tool with a punch plate. It consists of punch *1* and die *2* made from tool steel and welded to plate holders *3* welded at one end *4*.

The punch is 0.3-0.5 mm thicker than the metal to be blanked, while the die, at least 0.3-0.5 mm thicker than the punch. When this tool is used, as in the previous case, plates are secured to the bed and slide of the press. The tool is placed on the lower plate and

strip blank *5* is introduced between the punch and die. Such tools are used for blanking, punching, making small flanges, etc.

Multi-purpose tools are divided into tools with standard die sets (Fig. 96*a*, *b*) and tools with quick-change punches and dies (Fig. 97). The former are mainly used for simultaneous punching of many holes in large flat sheet work. The die set of such a tool consists of a punch

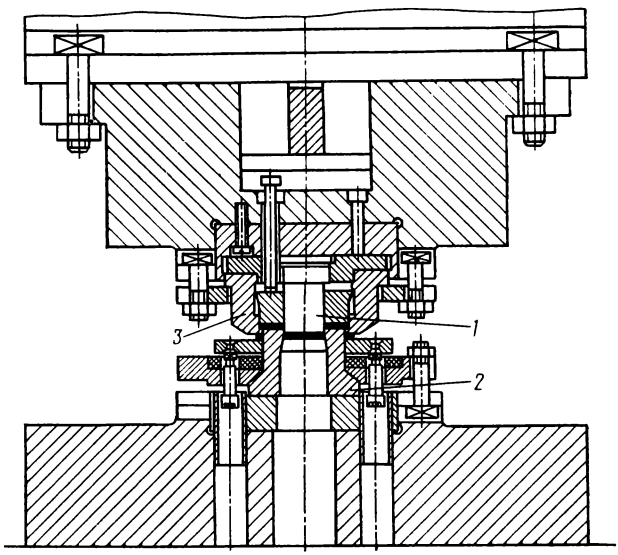


Fig. 97. Tool for blanking and punching a washer with interchangeable deforming parts (units)

holder and die shoe connected by means of four guide posts and bushings. The punch holder and die shoe may have T-shaped slots for securing a plurality of interchangeable working units comprising a punch holder with a punch, a die block with a die and a stripper. Such units are mounted in a die set. They can be easily unscrewed, shifted and secured in various positions depending on the location of holes to be punched in the stamping. Standard die sets with electromagnetic punch holders and die shoes are also employed. In such sets the interchangeable working units are held in position by electromagnets, which speeds up adjustment of the tool for new work.

Multi-purpose tools can be used to make various stampings element by element (first straight sections are made, then rounded corners, after this holes are punched, separate elements are bent, etc.). To effect this, a set of different working units and parts is needed so that each unit or part can be used for making a certain geometrical element of the work.

Tools with quick-change units or sets are mainly used for single-station pressworking and similar operations where the stamping dimensions vary within a relatively narrow range. Such tools have a die set with guide posts, permanent punch plates, die blocks, knock-outs, pilots; only punches, dies with some fasteners or die sets as a whole are interchangeable in them. Fig. 97 shows a tool for blanking and punching washers from a steel strip, 12 mm thick, comprising punch *1* for making holes, punch-and-die *2* for blanking the outer contour and punching holes, and blanking die *3*. All these parts are interchangeable, while the other ones are permanent.

4. Tools for Cold Die Forging

These tools usually have die sets with guide posts; the die sets accommodate the deforming, positioning, auxiliary and other parts. The die sets include massive punch holders and die shoes capable

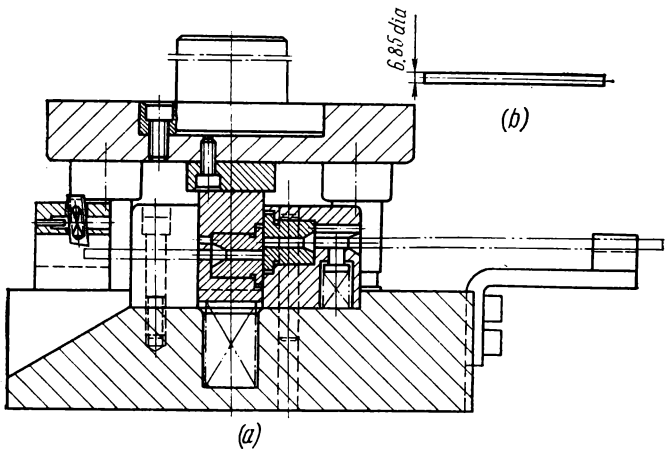


Fig. 98. Tool (*a*) for cutting off blanks (*b*) from bar stock

of withstanding high loads and reinforced guide posts and bushings ensuring accurate alignment even under considerable forging loads.

Cutting tools include tools for cutting out blanks from bars and thick plates, punching holes or webs, trimming and shaving.

Blanking tools (Fig. 98*a*, *b*) are provided with cutting bushings mounted on the upper and lower halves of the tool. The bar to be cut is fed through both cutting bushings up to the stop. Shearing is performed by displacing the movable bushing relative to the stationary one. The use of bushings instead of blades results in more accurate cuts and decreases mutilation of the material.

Tools for blanking round or shaped plate blanks for cold die forging, for punching holes, trimming and shaving are similar to those used in the pressworking of sheet metals. They are, however, more massive, sturdy, rigid, have more reliable guide posts, etc.

In tools for punching webs left in the holes after cold die forging, the working member is a punch. The die serves only for positioning the blank. The web drops through the die and the work is removed from the punch by a stripper.

In the mass production of parts by cold die forging, use is also made of compound tools capable of, say, trimming and punching at one station.

Direct and inverted extrusion tools (Fig. 99*a*) comprise massive punch holder *4* and die shoe *1*, guide posts *2* and bushings *3*. The punch holder carries punch plate *6*. Punch *8* rests on back-up plate *5* and is

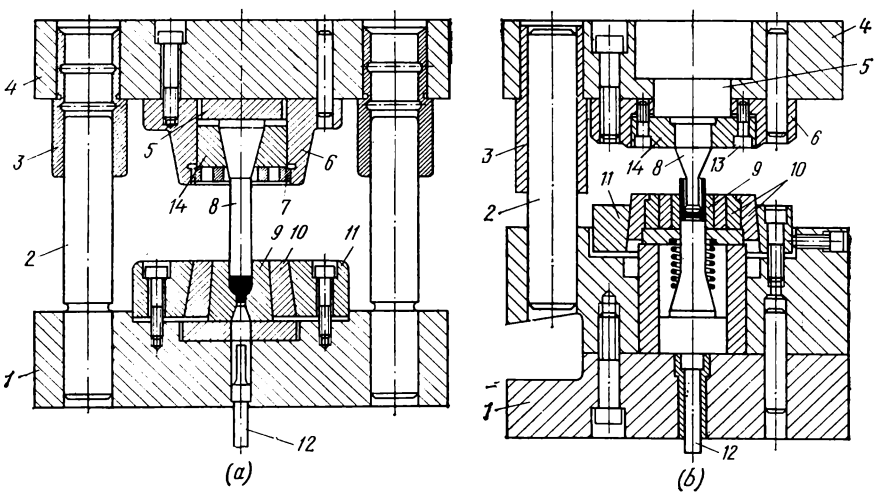


Fig. 99. Tool for cold die forging by direct (*a*) and inverted (*b*) extrusion

held in place by holder *14*. The holder is secured to the punch plate by threaded ring *7* (Fig. 99*a*) or screws *13* (Fig. 99*b*).

Die *9* is forced into one or several bands *10*, bears upon the back-up plate and is tightened to the die shoe by means of die block *11*. Knock-out *12* is actuated by the knock-out device of the press. The blank is placed directly in the die. The punch holder and the die shoe are bolted to the press slide and bed respectively.

A *tool for compound cold extrusion* of a socket wrench head is shown in Fig. 100*a*, *b*. A spherical or cylindrical blank is placed in the cavity of die *7* which is forced into band *13*. The die is secured to die shoe *1* by means of nut *15* and hold-down ring *14*. The blank is defor-

med by upper punch *5* during the downward movement of the slide. Metal flows both in the direction of the working stroke of the slide, thereby forming a square recess with the aid of lower punch *6* and in the opposite direction, forming an internal polyhedron.

Upper punch *5* with punch plate *8* is attached to holder *10* by means of nut *9*. The holder of the upper punch is secured to punch

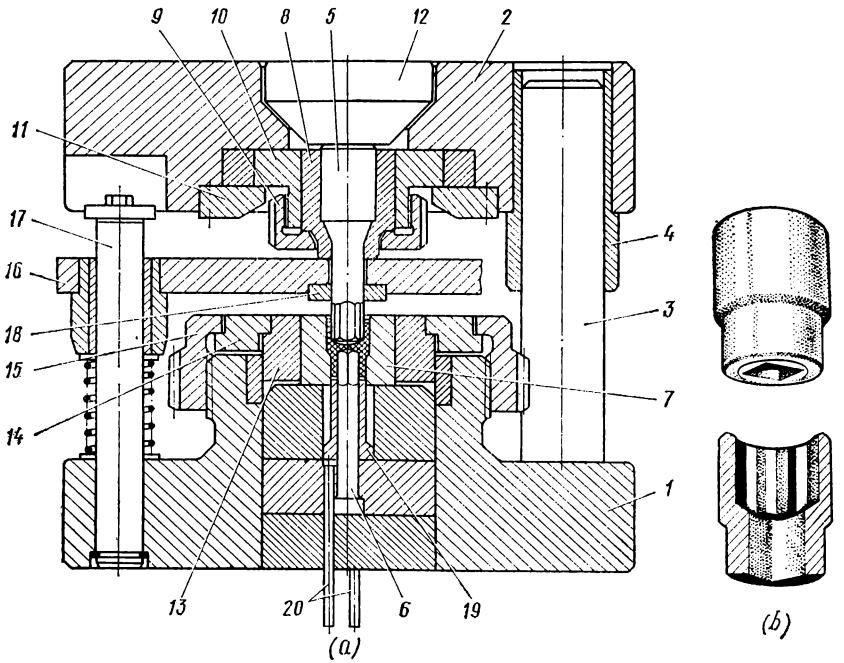


Fig. 100. Tool (*a*) for compound extrusion of a socket wrench head (*b*)

holder *2* with the aid of ring *11*. To decrease wear of the punch holder, the pressure is applied to it through cushion *12*.

The accurate alignment of the tool upper half relative to the lower one is ensured by posts *3* and bushings *4*. The workpieces are ejected from the die by tubular knock-out *19* which is driven from the press knock-out device by means of studs *20*.

To ensure removal of the blanks from upper punch *5*, stripper *16* is secured to two separate posts *17*. Replaceable inserts *18* are used to decrease wear of the stripper.

A *forming tool* (Fig. 101) has massive punch holder *5* and die shoe *8* which carry punch *6* and die *7* secured by means of punch plate *3* and die block *1*, respectively. Back-up plate *4* is mounted under the punch. A similar plate can be installed under the die.

The workpieces are ejected from the die by means of traverse *10*, rod *9* and knock-out *11*. When the press slide rises and approaches

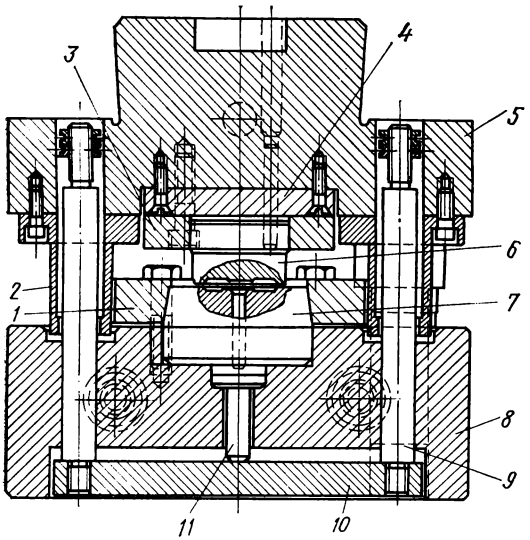


Fig. 101. Forming too

its top dead centre, bushings *2* lift traverse *10* with the aid of rods *9*. Knock-out *11* lifts out and ejects the workpiece from the die.

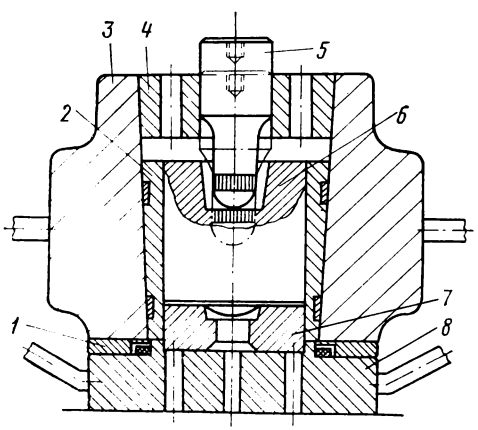


Fig. 102. Tool for forming pockets and recesses

The tool punch holder is secured to the slide by the dovetail joint with a wedge. Such tools can be used for sizing and coining.

A tool for forming pockets and recesses (Fig. 102) in massive blanks consists of punch *5*, die shoe *8*, guide ring *4*, casing *3* and receiving ring *7*. The punch travels inside guide ring *4*, casing *3* and receiving ring *7*. The punch travels inside guide ring *4*. Blank *6* is placed in special ring *2* mounted in casing *3* which bears against die shoe *8* or bushing *1* and the blank against receiving ring *7*. The tool is installed on the press bed. Forming is performed by the punch which is pressed down by a

special plate screwed to the press slide. When the operation is completed, the guide ring and punch are removed, the casing is turned upside down and placed on the press bed on an additional back-up ring. The slide presses the casing thus removing the blank from it.

5. Press Tool Certificate. Manufacture of Press Tools

The main documents outlining the characteristics of the press tool and its current condition are the press tool certificate and accompanying card.

Manufacturer ——— Certificate (press tool) No. ———

Press tool type ———

Mass ——— Overall dimensions ——— Shutheight (H_{sh}) ———

Article ——— Part ———

Operation ———

Press tool drawing No. ——— Date of designing ———

Name of designer, design bureau ———

Manufacturing cost ———

Problems encountered in manufacturing ———

——— Date and signature of quality inspector ———

Operation				Maintenance		
Date of putting into service	Date of return	Number of workpieces produced	Current condition, signature of quality inspector	Date of acceprance for repair	Date of retuun	Brief description of repair performed, signature of quality inspector

Fig. 103. Press tool certificate

Indicated in the press tool certificate (Fig. 103) are the plant and shop where the press tool is used, the tool manufacturing cost, overall dimensions, the rack and shelf where it is stored, and other data. Besides, the certificate contains information on operation, current condition and repairs performed.

The press tool accompanying card indicates the press on which the tool is installed, the number of stampings produced and the reason for withdrawing it from the press. The press tool certificate information is used to compile summary reports on the current condition of the press tool stock.

To make press tools for sheet metal stamping and cold die forging, production processes are elaborated for the manufacture of tool components and assembly of the tool. The press tool component blanks are pig iron and steel castings, forgings of different cross sections made from carbon and alloyed tool steels, rolled stock, various hard alloy pieces.

The initial stage of the production process comprises cutting out of blanks, casting of tool components, making of moulds for hard-alloy inserts.

After that the tool parts are subjected to preliminary machining which includes milling, planing, and drilling. Then follow jig boring, turning, grinding, electric-discharge and ultrasonic operations. Next, benchwork, thermal treatment and assembly operations are carried out. The assembled tool is subjected to tests and adjustment.

Tools are made individually, as a rule, widely using standard units and parts such as punch holders, die shoes, guide posts, bushings, shanks, punch plates and die blocks, fasteners. Such parts are made in batches at special tool-making plants or in large tool shops.

Punches and dies for small and medium-size press tools are made from rolled stock. If they are intended for heavy-duty work, the blanks are additionally forged. As outlined above, large punches and dies are frequently made sectional, composed of special rolled, forged or cast blanks. Other steel parts of press tools (guides, nests, pilots, stops, fasteners, etc.) are manufactured from rolled stock or calibrated steel. Blanks for punch holders and die shoes are cast from iron or steel.

Punch holders and die shoes are planed or milled and then ground to make their surfaces square and strictly parallel to each other. Holes made for forcing in the guide posts and bushes must be coaxial, and their axes strictly perpendicular to the surfaces of the punch holders and die shoes. This can be achieved by boring the holes separately or in both parts together.

When the holes are bored separately, use is made of precision jig-boring machines. In the case of joint machining, axial alignment of the holes is ensured by boring them with one setup or in a jig.

Next, holes for deforming and fastening parts are drilled and bored, slots are milled and holes are threaded in the punch holders and die shoes. A hardened die is bolted to the die shoe and the holes made in the former to receive studs are used as a jig for drilling holes for the same studs in the die shoe. The newly drilled holes are reamed and only then are the guide posts forced into the die shoe.

Guide posts and bushings are turned on a lathe, heat-treated, ground and lapped to each other (the posts are usually lapped to fit the bushings). The working and force-fitted surfaces of guide posts and bushings must be extremely accurate, strictly cylindrical and concentric with respect to one another.

Shanks are turned on a lathe and, if necessary, bored and threaded, but are not heat-treated.

To assemble a die set, first the bushings are forced into the punch holder. Then the guide posts are once more matched to the bushings and forced into the die shoe. The punch holder and die shoe are aligned and the travel of the upper half of the press tool with respect to the lower one is checked. Next, the punch is aligned with the die by reference to the position of the punch holder relative to the die shoe. the punch plate and other parts of the upper half of the tool are finally installed and the required holes and slots are drilled, reamed and bored.

The machining of the working (deforming) surfaces of punches and dies are the most critical and complicated operations. The outside surfaces of spherical dies are turned on a lathe and ground, those of other dies are planed, milled and ground. Then holes for fasteners are drilled and threaded, slots and projections are machined and only after that the working hole is machined. Round working holes are bored and preliminarily ground. Then the die is hardened, tempered, its face, working hole and bearing surface are ground.

Shaped working holes of dies are first milled on a vertical jig boring and milling machine. After heat treatment, the hole is ground on a grinding machine and is finally lapped by a toolmaker. Such shaped holes can be also made by electric-pulse machining. After the working holes are finished, the punches are matched to the dies.

At modern plants, several hundred dies are used and stored. The organization of storage and supply of press tools in a shop is usually the responsibility of the shop tool office, which determines the quantities and types of tools required for the shop, orders them from the toolmakers, accepts new tools, keeps records of the number and condition of the tools, organizes their storage and repair and writes off worn tools, etc.

Small and medium-size tools are kept in the shop storeroom on multi-level racks in definite places marked with the press tool No. The rack places are allocated according to the tool types (blanking, drawing, punching, etc.) or to the kinds of stampings (plates, caps, etc.). Large heavy tools are stored on special grounds, on metal horses or supports arranged near the presses. Very large tools are kept on the floor.

Review Questions

1. How are the press tools divided according to the operating principle?
2. Name the components of a plain blanking press tool.
3. What materials are used for making press tool parts?
4. Describe the design features of cold die forging tools.
5. What data are entered into the press tool certificate?

Chapter VIII

PREPARATION OF MATERIALS FOR PRESSWORKING

1. Preparatory Operations

Preparation of sheet material and bar stock for pressworking involves different operations, such as straightening, pickling, washing, annealing, drying, skin rolling.

Rolled or cut sheets, bands and strips often require *straightening*. This operation is usually performed on roll straightening machines which offer high quality and efficiency of straightening. The machines can be two-, four- or multiroll ones. The metal is passed through the rolls for several times.

In small-batch production hand straightening of sheet metal is performed on dressing plates.

To remove scale and corrosion from the surface of sheet or bar stock, use is made of *pickling* in strong solutions of sulfuric, nitric or hydrochloric acids, solutions of caustic alkali, sodium salt and hydrochloric acid, etc. Special additives often added to pickling solutions, which settle on the surface of the metal and protect it against excessive corrosion by the solution and penetration of hydrogen into the metal, thus precluding undesirable brittleness of the latter.

Some manufacturers use electrolytic pickling, pickling in salt melt and gas pickling. Pickling in salt melt is carried out at a temperature of from 600 to 700°C which provides for simultaneous relieving of stresses. To descale wire up to 6 mm in diameter, mechanical methods are employed, such as passing the wire between brushes rotating in opposite directions.

Pickling lasts from 5 min to 1.5 h depending on its purpose and type of solution. Pickling tanks are made from concrete or steel coated with acid- and alkali-resistant materials. The tanks are equipped with heaters and agitators. The pickling conditions for different materials are specified in the respective reference books or instruc-

tions. The solution concentration should be checked one or two times per shift. When loading bars or sheets into the pickling tank, special spacers should be placed between their rows.

Pickling in weak solutions (degreasing) is needed to remove surface oil and dirt before drawing or other forming operations, before heat treatment and after pressworking. Weak solutions used for pickling carbon steels are alkali or acid solutions of weak concentration: 3-5% aqueous solutions of H_2SO_4, HCl, NaOH heated to a temperature of 50-60°C.

Pickled articles are carefully washed to remove the residue of pickling solutions, dirt, lubricants, etc. Washing is usually carried out in two or more tanks, the first one being filled with cold running water, the second, with hot water (60-80°C), etc.

Pickling and washing are performed either in separate baths or on automatic production lines consisting of several tanks, into which are automatically and consecutively immersed metal baskets containing the parts.

Heat treatment is used to obtain the required structure and mechanical properties of the material. For instance, the bars to be drawn are annealed, which simplifies the drawing operation and provides for obtaining a bar with particular mechanical properties. Annealing is usually employed as an intermediate operation in drawing. The annealed bar is subjected to only low-degree finish reduction or is passed through a wooden die without any substantial change in the properties of the annealed metal. The purpose of annealing is to form a structure more suitable for cold working. Annealing is carried out mainly in shaft and horizontal hearth furnaces. The post-annealing properties of metal depend on the temperature and duration of the operation, chemical composition of the material, heating and cooling conditions.

Medium-carbon steels for cold upsetting are annealed for 4 to 23 h depending on the initial condition of the metal. The annealing time for aluminium and its alloys is up to 6 h.

Metal intended for cold upsetting is subjected to drawing which ensures high accuracy and surface finish. Drawing is accomplished in one or two stages with intermediate annealing. The mechanical properties of metals change drastically after drawing: the yield strength increases and the per cent reduction of area and elongation decrease.

Sheet metal intended for producing intricate drawn parts that are to be subsequently painted (facing parts for motor vehicles, etc.) is subjected to skin rolling. Skin rolling is cold rolling of sheet with a light reduction of about 0.5-2 per cent to eliminate the yield elongation zone of the curve. The yield elongation zone causes the loss of stability by the metal during drawing, hence flaws, such as orange peel, etc., on the parts. The skin rolling effect disappears as the metal

ages, which should be borne in mind when elaborating the pressworking processes.

Lubrication is used in pressworking to reduce the deformation force (especially in drawing, ironing, bulging, bending and other forming operations), protect the surfaces of the metal being worked against damage, prolong the life of the tool, facilitate the removal and ejection of the part, etc. Lubrication must considerably decrease the friction of the metal against the tool parts, create a strong film on the blank surface, capable of withstanding high pressures without breaking; adhere well to and spread uniformly over the surface of the metal; be easy to remove from the surface of the metal; it must not damage the surfaces or cause any harm.

Before applying lubricants to parts, the latter should be carefully cleaned of dirt and oil by washing or pickling with subsequent washing, and drying.

The lubricants employed in pressworking of sheet metals may be liquid, viscous and solid.

Liquid lubricants used for carbon steels are soap emulsions (water or oil), mineral oils and special compositions. Viscous lubricants are viscous oils (grease, commercial vaseline, etc.) or special compositions made of oils, fats, water and fillers. The fillers make the oil film stronger and prevent its being squeezed out from the contacting surfaces. They absorb the lubricants and emit them under the high pressures developed during deformation. Fillers include talc, graphite, chalk, wood flour, etc.

Liquid and viscous lubricants give the best results when they contain surfactants (oleic and stearic acids, etc.). These substances, added in very small quantities (a few fractions of one per cent), improve the adhesion of lubricants to metal.

Solid lubricants are coatings of special chemical substances, such as a phosphate coating, or easily-deformable metals, such as copper.

Good results are offered by molybdenum disulfide: the parts produced with the use of it feature high surface finish.

Liquid and viscous lubricants are applied to the surface of metal by means of spray guns. Parts are sometimes immersed in tanks with a heated viscous lubricant.

Cold die forging is characterized by high specific loads, heating of metal owing to the heat effect in plastic deformation, considerable strain; therefore, the quality of parts depends greatly upon proper treatment of blank surfaces. In this case *coatings* are used as independent lubricants.

Lime pretreatment is used for steels intended for one-step cold upsetting. After drawing, pickling and washing, the metal is immersed in an 8-per cent solution of lime at a temperature of 90°C. The steel treated in such a way is ready for machining.

The shortcoming of this method is that corrosion may appear under the lime coating under adverse conditions and in prolonged storage.

Another method is to coat the metal with borax, wherein the pickled metal is washed, then immersed into 5 to 8-per cent solution of borax at a temperature of 90 °C and dried at a temperature of 300-500 °C. The advantage of such a coating is that the metal may be stored for a long time and no lime dust contaminating the tool and equipment is formed in pressworking. The borax-coated metal is subjected to drawing.

The method of phosphatizing with subsequent soaping has found the widest application in cold die forging of carbon and low-alloy steels both in this country and abroad. This method resides in treating the metal with phosphates of zinc, manganese, iron, etc. The treatment is performed by hot, cold, jet, electrochemical processes, etc.

Prior to phosphatizing the metal is degreased, pickled, washed with cold and hot water, then a layer of phosphates is applied to the blank surface. Next, the blank is washed with water and neutralizer and is soaped. The phosphates form a plastic and sufficiently strong interlayer between the metal and tool; they are good lubricants and reliably retain soap, oil and other substances on their surface.

The most common method of applying the phosphate layer is immersion of blanks into the phosphate solution. There are a wide variety of phosphatizing installations with circular and linear arrangements of tanks.

Some difficultly deformable alloys are coated with varnishes.

2. Blank Layout

Blank layout is positioning of blanks on a sheet, band or strip. The best layout gives the minimum amount of scrap in the form of slugs and webs. The slugs are the metal left between the blanks or between the blanks and the edge of the sheet or band.

Scrap resulting from punching is termed webs.

The positioning of blanks depends on the geometry of stampings to be made. Its quality is shown by the material utilization factor μ

$$\mu = \frac{A_{us}}{A_{bl}} \times 100\%$$

where A_{us} is the usable area of the sheet or strip, m^2, and A_{bl} is the area of the blank, m^2.

The blanks can be positioned with or without scrap (Fig. 104*a*, *b*, *c*, *d*, *g*, *h*, *i* and Fig. 104 *e*, *f*, respectively). The material utilization factor in scrapless layout approaches 100 per cent. To reduce scrap in the mass production of large parts (for example, blanks for

motor car fenders and bonnets), non-standard sheets may be ordered if standard sheets offer a low material utilization factor. However, the cost of a non-standard sheet is 10-15 per cent higher.

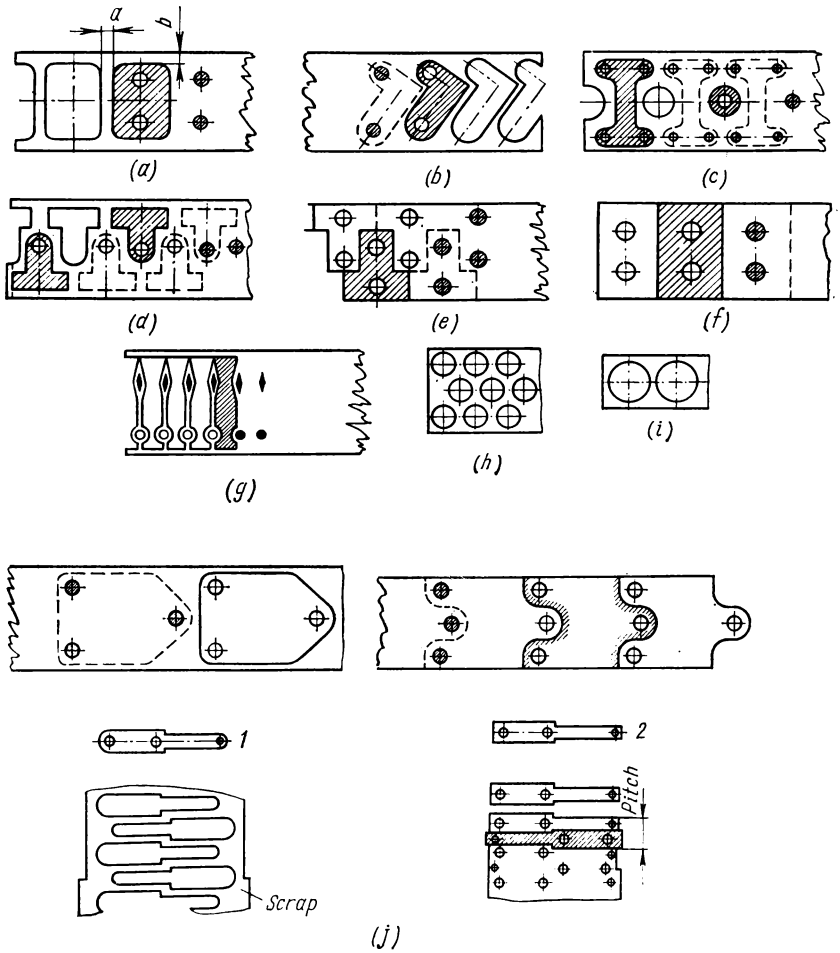


Fig. 104. Blank layout
(*a*, *b*, *c*, *d*, *g*, *h*, *i*) with scrap; (*e*, *f*) without scrap; (*j*) changing the geometry of sheet stampings to reduce scrap in blanking; *1*—old shape; *2*—new shape

When designing a part, layout convenience is always taken into account. Scrap can be considerably reduced by changing the design of a part.

Round parts are blanked in one or more rows (Fig. 104*h*, *i*). They are arranged either parallel or staggered. The optimum layout for

round parts is in staggered rows, the factor μ growing with the number of rows. However, this number cannot be too great, otherwise, wider strips and larger and more complicated tools will be needed.

Before making shaped blanks from metal, several of them are cut out from thick paper and positioned on a model sheet or strip to find the most economic arrangement.

Before making shaped blanks from metal, several of them are cut out from thick paper and positioned on a model sheet or strip to find the most economic arrangement.

To determine optimum blank layout in mass production, use is made of computers which provide for evaluating a plurality of variants and selecting the optimum one.

There are several types of blank layout: straight, (Fig. 104*a*, *f*), angular (Fig. 104*b*), inverted (Fig. 104*d*, *e*), combined (Fig. 104*c*), multi-row (Fig. 104*h*) and with cutting out of webs (Fig. 104*g*). The straight layout is used for simple work — rectangular or square. The angular layout suits for L-shaped work or other intricate shapes, and the inverted one, mainly for T-, U- and W-shaped parts.

When the scrap can be utilized, combined layout is used. Multi-row layout is used in large-batch and mass production of small stampings, while that with cutting out of webs is resorted to when making such parts as watch or clock hands or other slender parts.

Sheets are cut into strips cross- and lengthwise. For higher productivity it is better to arrange the strips along the long side of the sheet since more stampings can be obtained in this case. When laying out blanks, account should be taken both of the amount of scrap and of the possibility to use it for making other parts.

Table 3

Minimum Dimensions of Webs and Waste Ends

Thickness of material, mm	Web and waste end width, mm		Thickness of material, mm	Web and waste end width, mm	
	a and *b*	a_1 and b_1		*a* and *b*	a_1 and b_1
0.3	1.4	2.3	2.5	1.8	2.8
0.5	1.0	1.8	3.0	2.0	3.0
1.0	1.2	2.0	3.5	2.2	3.2
1.5	1.4	2.2	4.0	2.5	3.5
2.0	1.6	2.5			

Note. *a*—webs between small blanks of a simple shape (see. Fig. 104), a_1—webs between large or intricate blanks, *b*—waste end when using side blankholder, b_1—waste end without blankholder.

It is common practice to cut up a sheet into strips of different widths from which different parts are made. This results in the economy of metal.

The dimensions of webs (Table 3) depend on the thickness and hardness of the material, the dimensions and shape of the blanks, the kind of the rest, use of blankholders, etc. The dimensions are so selected as to ensure blanking of parts along the entire contour without breaking the webs or pulling them into the die and to maximize the economy of metal.

3. Shearing of Blanks

Sheet material is cut into strips or separate blanks in pressworking shops on shears or presses with shearing tools. Blank preparation sections of the shops are equipped with parallel, guillotine and circular shears.

The *parallel shears* are used for cutting thin metals, when cut surface and accuracy requirements are high, and for non-metallic materials. Such shears cut the material throughout the entire separation line at once.

To obtain strips and blanks of the required shape and dimensions, use is made of front, rear, side and angular stops.

The *crank guillotine shears* have found a wider application. These are intended for cold cutting of metal from 0.5 to 30 mm thick or more with a cutting length of up to three metres. These shears do not cut throughout the entire sheet width at once so that the shearing force is a fraction of the force required in the case of parallel shears.

Two-crank shaft *3* (Fig. 105*a* and *b*) with flywheel *4* is driven by an electric motor through V-belt and gear drives. The plate to be cut is arranged on table *7*, held down by a clamp and cut by upper movable blade *2* and lower fixed blade *1*. The clamp is actuated by a lever-and-cam device. The crank mechanism of the shears is engaged by clutch *5*. The shears are controlled from console *6* or with the aid of pedal *8*.

To prevent sagging of long blanks at shearing, various rests are used.

The shears blades are made one-piece or composite. The one-piece blades are made from steel grades У8А, У10А, Х12, Х12Ф1, etc. Cutting inserts for the composite blades are made from steel grades 6ХС or Х12Ф1 and the other part, from steel grades 45 or 50. The cutting inserts are screwed or riveted to the blade body. Depending on the properties (especially hardness) of the material to be sheared, different blade sharpening and setting angles are used (from 2 to 6°).

To cut wide strips in coils into narrow ones, use is made of *circular shears* (Fig. 106) with one or more pairs of disk blades *1* mount-

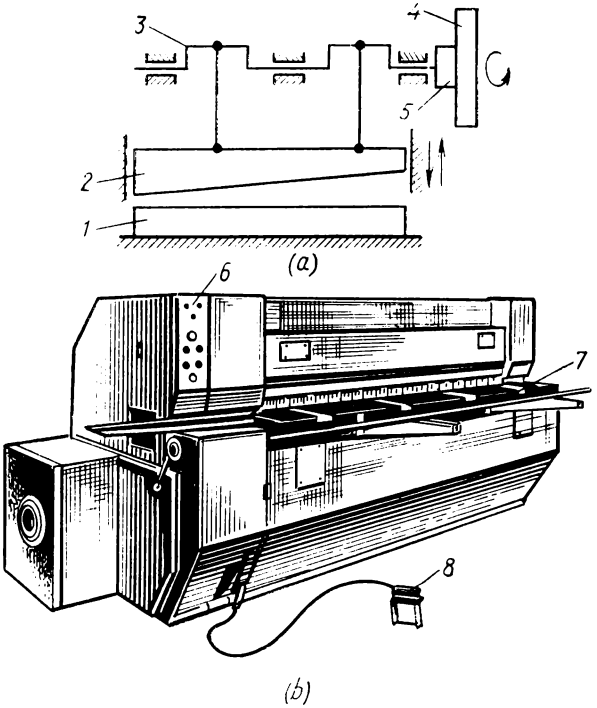


Fig. 105. Crank guillotine shears
(*a*) mechanical diagram (blankholder not shown); (*b*) general view

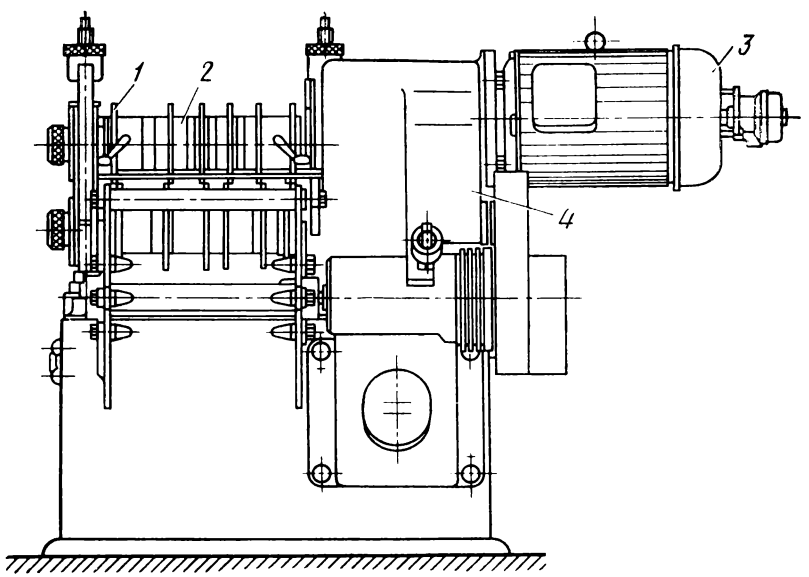


Fig. 106. Circular shears with cylindrical blades

ed on parallel shafts *2*. The shafts are rotated from electric motor *3* through V-belt and gear *4* drives. The blades draw in the strip to be cut. The strip unrolls from one coil and is wound after being cut onto several others, the number of which corresponds to the number of strips obtained.

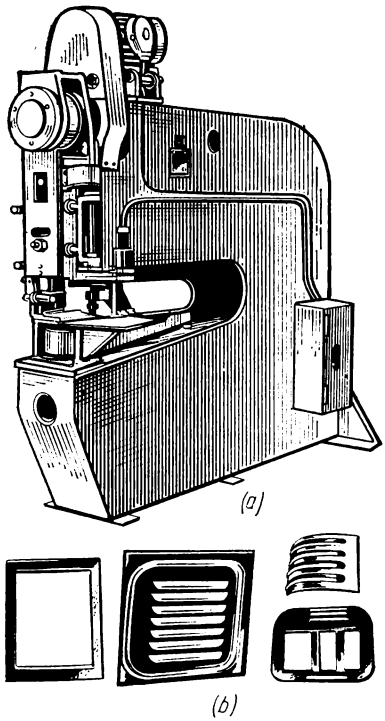


Fig. 107. Punching shears H535 (*a*) and workpieces produced on them (*b*)

For the straight and shaped cutting of sheets and plates in single-piece production, use is made of *circular shears with tapered disk blades*, and of *punching shears* (Fig. 107*a*, *b*). These have a C-shaped frame whose open part accommodates the working tools. Circular shears have tapered blades driven by a motor via a V-belt and gear drives, while punch shears have inclined straight blades, of which one is fixed and the other is reciprocated by an eccentric mechanism.

The second blade of the one-disk shears is made in the form of a fixed strip.

The two-disk shears can be adapted by installing special fixtures and tools to bending and flanging of sheets, the punching shears, to flanging and riffling.

The two-disk shears are equipped with blades of three types: with parallel axes, with one blade inclined and with two blades inclined. These are used for cutting plates 20 to 30 mm thick with a speed of from 1 to 20 m/min. The shears with inclined upper and lower blades are designed for cutting blanks with small radii of curvature.

The materials are cut on the two-disk shears manually to the marking or by means of special fixtures.

Multi-disk shears are employed in the mass production mainly for cutting thin sheet materials. These shears ensure higher efficiency in longitudinal cutting than the crank ones.

The distance between the blades is set by measuring rings. The disk shears blades are made from the same materials as those of the crank plate shears.

Vibrating shears with 2 000 to 25 000 strokes per minute and a blade travel of 2-3 mm are used for cutting small-radius (up to 15 mm)

curved blanks from sheets up to 10 mm thick to the marking or by templates. Strips are cut into single blanks in shearing tools on presses.

The method of producing blanks from bars, wires, or pipes depends on the cross section shape of the source material and quality requirements to be met by the blanks. Bars, wires or pipes can be cut both on special shears and in tools on presses and automatic machines. Bar and pipe blanks are also obtained on circular saws and turning lathes.

In addition to the above method, bars are cut in bushing tools, by shearing in tools with a differential grip and by twisting.

When cutting in bushing tools, the die and punch are two bushings shaped according to the bar profile. The perpendicularity and flatness of the cut are ensured by adjusting the clearance between the cutting bushings.

The method of cutting bar stock by shearing with a differential grip at both sides of the cutting plane ensures a better quality of the blanks. The force of gripping of the bar and blank being cut is changed in proportion to the cutting force which precludes distortion of the bar cross section shape.

The twist cutting resides in turning one part of the bar relative to the other, clamped with a constant force.

Using a circular saw or a single- or multi-spindle lathe for cutting blanks is economically unfeasible: such blanks are 4 to 6 times as expensive as those sheared in press tools. More economic and efficient are automatic lathes which offer higher quality of the cut than fast-speed saws.

The cold upsetting single-station automatic machines are most economical for making blanks in the mass production of parts. Apart from cutting, such machines can be used for sizing and chamfering the blanks at a rate of several thousands per hour.

Revew Questions

1. What is the purpose of lubrication in pressworking?
2. Describe preparation of materials for pressworking.
3. What is the material utilization factor?
4. Describe the equipment used for cutting blanks.

Chapter IX

PRESSWORKING EQUIPMENT

1. Types of Pressworking Equipment

Pressworking equipment is divided into mechanical presses, hydraulic presses, hammers, rotary machines, automatic machines, various shears, high energy pulse forming machines, etc.

Multi-purpose and special mechanical and hydraulic presses and automatic machines make the backbone of the pressworking shop equipment.

The multi-purpose presses are designed for performing various pressworking operations such as blanking, bending, drawing, etc., while the special ones, for only certain operations, such as deep drawing, special bending, etc.

The working tools of the mechanical presses are actuated by an electric motor through a mechanical transmission. The working tools of the hydraulic presses are driven by a hydraulic cylinder whose plunger is moved by the pressure of the working fluid.

The automatic machines used in the shops are the forging and stamping machines in which the blank is fed, transferred from one station to another and the article is withdrawn automatically.

The mechanical and hydraulic presses, automatic machines and other pressworking equipment are constantly modernized and improved.

Their productivity as well as mechanization and automation levels are increasing, their maintenance is being improved and made more convenient. Besides, there are trends for expanding the production capacities of the equipment and raising the labour safety standards.

2. Mechanical Presses

The majority of the pressworking operations are performed on crank presses. Such presses are reliable in operation, economical and simple to control.

The working motion in the crank presses is created by a crank gear. Rotating crank *5* (Fig. 108*a*) imparts reciprocating motion to slide *3* of the press via pitman *4*. The slide moves along guides *2*.

The uppermost position to which the slide is lifted is called its top dead centre (TDC), while the lowermost one, the bottom dead centre (BDC).

The distance from the slide lower face at its top dead centre to bed *1* is called *open height* H_O, and from the slide lower face at its bottom

dead centre to the bed — *shutheight* H_s of the press. The *stroke of the press*, H, is the distance between the top and bottom dead centres. It is equal to the double radius of the crank. The time required for the slide to travel from the top dead centre to the bottom dead centre and back to the top dead centre is called the *slide double stroke time*

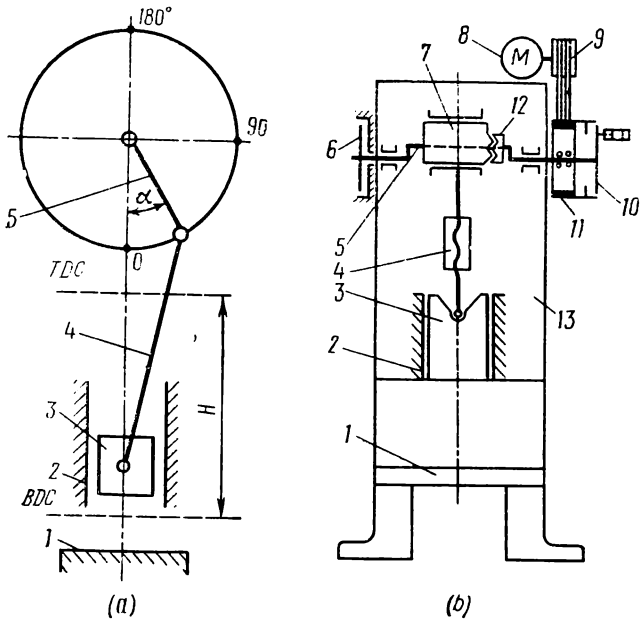


Fig. 108. Single-crank single-action mechanical press (*a*) crank gear operating diagram; (*b*) press diagram; *1*—press bed; *2*—slide guides; *3*—slide; *4*—pitman; *5*—crankshaft; *6*—brake; *7*—eccentric bushing of a stroke adjustment mechanism; *8*—electric motor; *9*—pulley; *10*—friction single-disk clutch; *11*—flywheel; *12*—dog clutch of a stroke adjustment mechanism; *13*—frame

Figure 108*b* shows a diagram of a *crank press*. The press comprises the following main units: bed *13*, slide *3*, clutch *10*, brake *6*, a drive and lubrication and control systems. Torque from electric motor *8* is transmitted through V-belt drive *9* to flywheel *11* freely rotating on crankshaft *5*. The same crankshaft carries clutch *10* and brake *6*. Crankshaft *5* starts rotating only when friction clutch *10* is engaged. To stop the crankshaft with the clutch disengaged, use is made of brake *6*. When the brake is applied, the crankshaft stops, while flywheel *11* keeps on freely rotating on it. Rotation of the crankshaft is converted by pitman *4* into reciprocation of slide *3*. Eccentric bushing *7* and dog clutch *12* serve for adjusting the slide stroke.

Pitman *4* is connected to slide *3* by a screw. The screw is driven into the pitman and its spherical head enters into a corresponding seat of the slide. Such a joint provides for changing the open and the shut height of the press and for installing tools of different height on the press, and simplifies the set-up work.

The slide moves in guides *2* of the press bed. The lower half of the tool is mounted on bed *1*, while the upper one is secured to slide *3*. The space between the bed and the slide is termed the tool space of the press.

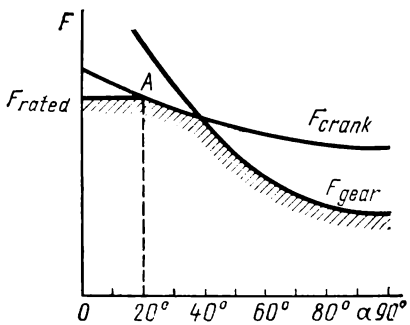


Fig. 109. Crank press permissible load curves

The press is engaged by pressing control buttons or a pedal.

The force at a crank press slide depends on the crank angle of turn and increases as the slide approaches the bottom dead centre. The permissible force on the slide is limited by the strength of crankshaft F_{crank} and gears F_{gear} (Fig. 109). The rated force indicated in the press certificate is the force on the slide when the crank is short of the bottom dead centre for α_r. For single-crank single-action presses with a one-side drive $\alpha_r = 20°$, for double-action presses $\alpha_r = 10°$. In the case of a two-side drive, these values will be 30 and 20°, respectively.

The permissible force curve (the shaded contour in Fig. 109) should be indicated in the press certificate. The operation force curve should be inside said contour without intersecting it.

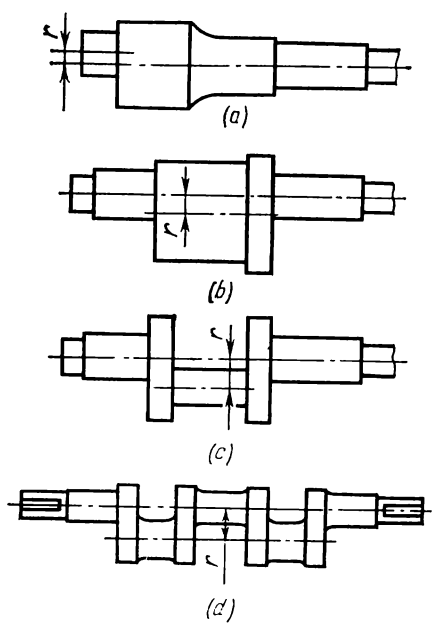


Fig. 110. Types of shafts
(*a*) crank; (*b*) eccentric; (c) single-throw; (*d*) double-throw, *r*—crank radius

The mechanical presses with a crank gear are called crank presses owing to the type of the shaft drive. The same term is conventionally applied to the presses with other types of shafts: eccentric and single- or double-throw bent shafts (Fig. 110). The throws of a bent shaft are often called cranks.

As regards their operating principle, the mechanical presses are divided into single-action presses with one slide, double-action pres-

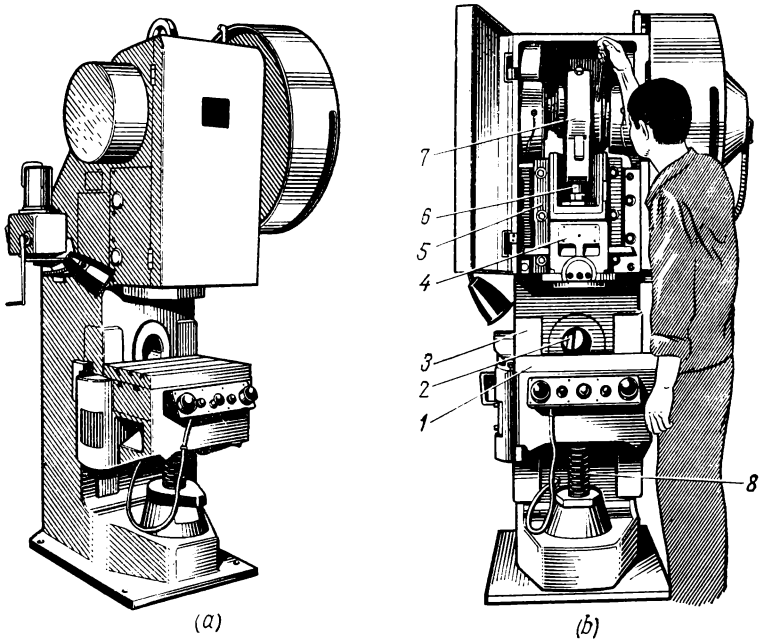


Fig. 111. Single-crank single-action open pillar press КД1424 with a rated force of 25 tf

(*a*) general view; (*b*) operator adjusting slide stroke; *1*—press bed; *2*—hole in frame for mounting horn; *3*—frame; *4*—slide; *5*—slide guides; *6*—adjustment screw; *7*—pitman; *8*—screw

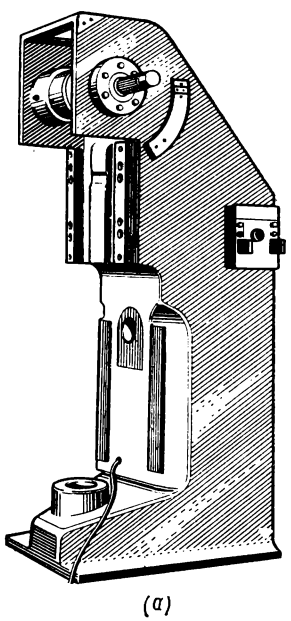
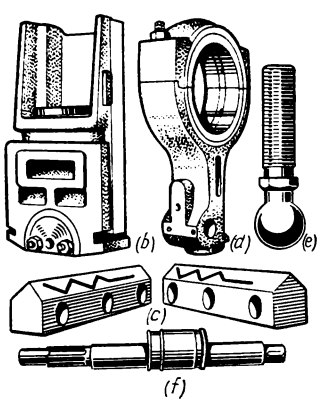


Fig. 112. Main subassemblies of a mechanical press

(*a*) frame; (*b*) slide; (*c*) slide guides; (*d*) pitman; (*e*) pitman adjustment screw; (*f*) eccentric shaft



ses with two slides (inner forming slide and outer blankholding slide) and triple-action presses with three slides (outer blankholding slide, inner forming slide and another forming slide moving in the opposite directions).

Depending on the number of cranks, single-crank, double-crank and quadruple-crank presses are distinguished. According to the design of their frame, there are open gap-frame mechanical presses

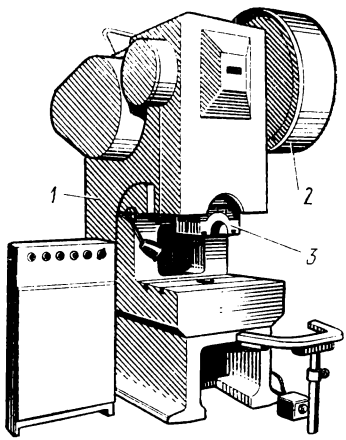


Fig. 113. Double-arm single-action mechanical press К2130 with a rated force of 100 tf
1—frame; *2*—flywheel (enclosed); *3*—slide

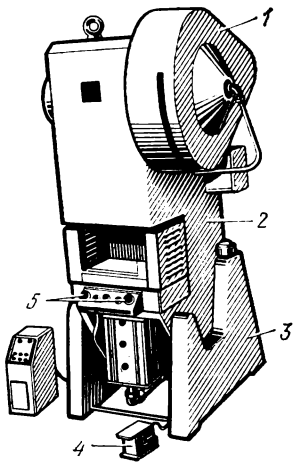


Fig. 114. Inclinable double-arm single-action mechanical press КД232 with a rated force of 25 tf:
1—flywheel (enclosed); *2*—frame; *3*—bolster; *4*—control pedal; *5*—two-hand push-buttons

where the working space is accessible from three sides (Fig. 111*a*, *b*); closed presses where the frame is made as a closed structure and the tool space can be reached from two sides (Fig. 112); pillar presses the frame of which is a pillar of a box-shaped or other cross section (Fig. 111); double-arm presses where the frame is made from cast, welded or composite frames (Fig. 113); inclinable presses where the frame is made turnable in the vertical plane (Fig. 114). Fig. 112*a* to *f* shows the main subassemblies of a mechanical press.

The mechanical press is called vertical if its slide moves in the vertical plane. If the slide moves in the horizontal plane, the press is called horizontal.

The frame of the open presses provides for feeding the stock both along and across the press front (the press front is its side facing the operator's station). The inclination of the inclinable press frames (Fig. 114) simplifies removal of scrap through a chute. The fixed

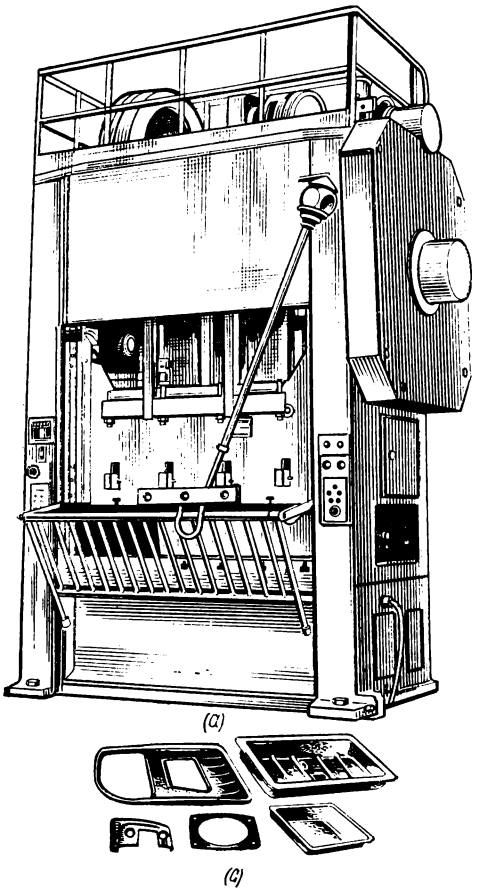
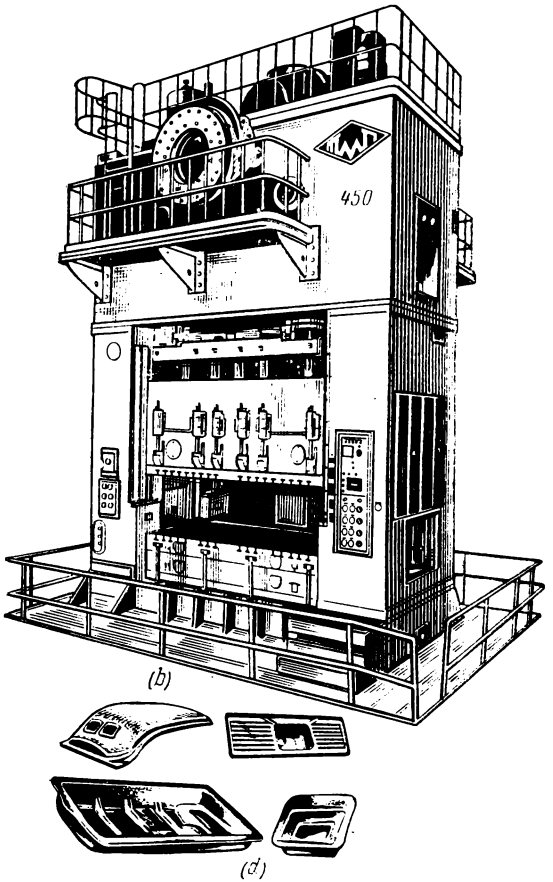


Fig. 115. Single-action closed mechanical presses
(*a*) double crank press K3732, rated force 160 tf; (*b*) four-crank press K4037, rated force 450 tf; (*c*, *d*) examples of stampings

angles of inclination which are set manually by rotating a screw are 10, 15, 20, 30 and 45°.

In closed mechanical presses the tool space can be reached from the sides through the ports in the frame arms (Fig. 115*a*, *b*). These ports widen the production possibilities of presses, provide for installing mechanization and automation means.

Frames of small presses (see Figs. 111 and 112) are cast from iron and sometimes from steel. The frames welded from steel plates and slabs find wider application today. Such frames are lighter, stronger and cheaper. The welded frames can be one-piece or composed from separate welded parts interconnected by bolts. For instance, the frame of the USSR-made press, type K3732 (Fig. 115*a*, *b*) consists of a



bed, two arms and a traverse integrated by four bracing studs. Fig. 115*c*, *d* shows the articles produced on these presses.

The press frames are usually integrated with the bed. The beds are made with one central or several holes for accommodating knock-outs and removing stampings and scrap. Secured to the press bed is a bolster plate which carries the lower part of the tool.

The open presses may have a lifting bed (see Fig. 110) and hole *2* in the frame for accommodating a horn. The latter serves for installing the lower half of the tool when punching holes and performing other pressworking operations in round and hollow blanks of a considerable length and diameter, such as pipes, drums, etc.

The press bed is lifted manually (see Fig. 111) by turning screw *8*.

The press slides are cast from iron СЧ21-40 or modified strong cast irons or are welded from steel. The slides of automatic cold upsetting machines, etc. are cast from steel. The slides of the presses with a force of up to 100 tf have a hole for receiving the tool shank. The shank is clamped by the slide insert which is secured by means of bolts and so the upper half of the tool is held in place.

In medium- and large-size presses, the slides are provided with T-shaped slots and holes for securing the upper half of the tool. The lower half is installed on the bed or bolster plate and is bolted with the aid of hold-down bars and clamps. The bolt heads are introduced into the T-shaped slots made in the bed or bolster plate.

To ensure accurate alignment of the slide, V-guides are installed on the frame.

The guides of the single-crank open press (Fig. 112*c*) are of the V shape with an apex angle of 90°. The slides may have also prismatic guides of a trapezoid or other cross section.

The crank, eccentric and bent shafts for the presses are made from alloy steel by forging or pressing with subsequent machining.

Crankshafts rotate on sliding bearings which are one-piece in some pillar presses and are made in the form of two liners in all other types of presses. The sliding bearings are lubricated with grease or other viscous lubricant.

The flywheel of a press is designed not only for rotating the crankshaft, but also for accumulating kinetic energy. The press uses the maximum amount of energy during its working stroke, i.e. in stamping, when the flywheel gives up some of the stored energy and its angular velocity is decreased by 15-20 per cent. The idle stroke of the slide does not require much energy and during this period the flywheel restores the required speed of rotation with the aid of the electric motor.

Utilization of additional energy accumulated by the flywheel provides for decreasing the required power of the press drive motor. Pressworking operations are started when the flywheel speed of rotation, hence the energy accumulated by it, reach the required level.

If the amount of energy consumed during pressworking exceeds that accumulated by the flywheel within one stroke, automatic stamping is impossible (the press will soon stop). At the same time, when similar parts are stamped by single strokes the press operates normally since the flywheel has enough time to accumulate the energy because not each stroke is utilized. Flywheels are made by casting. In small presses these are mounted directly on the crankshaft. Such presses are high-speed ones (hundreds of strokes per minute). Large crank presses which develop great forces on the slide are relatively low-speed. Torque from the electric motor in such presses is transmitted through one or several intermediate shafts interconnected by gearing (Fig. 116*a*, *b*, *c*). Heavy presses often have two-side drives for

imparting rotation to the crankshaft (Fig. 116*d*), which provides more uniform loading of the latter.

The pitman (see Fig. 112) is fitted with its upper part on the eccentric or crank neck of the shaft. The lower part of the pitman is threaded to receive a screw with a ball joint (see Fig. 112*d*).

In an open single-crank single-action pillar press (see Fig. 111), pitman 7 is fitted over the eccentric bushing mounted on the eccentric neck of the shaft (see Fig. 112*f*). The eccentric bushing and shaft

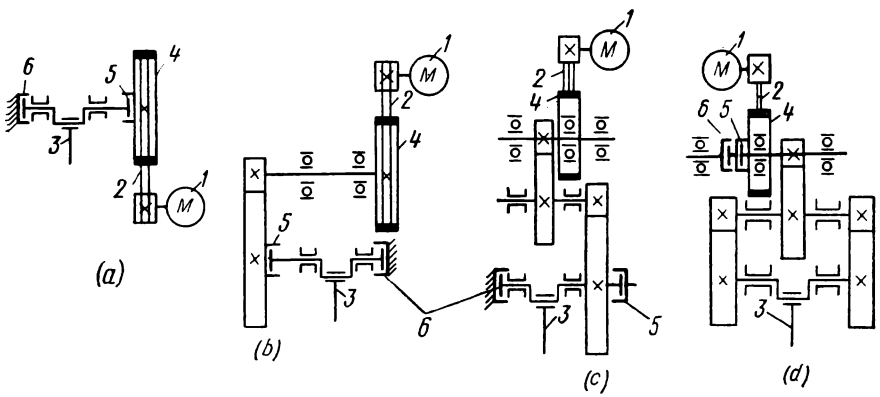


Fig. 116. Diagrams of mechanical press drives
(*a*) single-stage; (*b*) double-stage; (*c*) triple-stage; (*d*) two-side triple-stage; *1*—electric motor; *2*—V-belt drive; *3*—crankshaft with a pitman; *4*—flywheel; *5*—friction clutch; *6*—brake

are connected by a dog or gear clutch (see Fig. 108*b*). The slide stroke is adjusted by turning the eccentric shaft bushing. When the bushing and shaft eccentricities coincide, the slide stroke is maximum, if they are opposite, the stroke is minimum.

Modern double-arm closed presses (see Fig. 115) have an enclosed drive whose movable parts are generously lubricated or run in an oil bath thus reducing wear and noise in operation.

The clutches which connect the flywheel to the crankshaft or intermediate shaft ensure periodic engagement and disengagement of the press tools with the motor and flywheel rotating continuously. The modern presses are mainly equipped with single-disk and multidisk friction clutches. Positive clutches can be found in some old-type presses. The positive clutches engage and disengage the flywheel and the crankshaft only at a definite position of the slide near the top dead centre. Thus, positive clutches do not permit the crank gear to be engaged and disengaged at any position of the slide or the latter to be inched, i.e. moved through short distances which is necessary for adjustment. Therefore, the setter-up has to rotate the press crank gear manually by its flywheel.

Since they work with impact loads, positive clutches rapidly wear and their engagement members frequently break. This may cause failure of the clutch and unexpected continuation of the slide movement after the pedal is released, which may lead to an accident or injury.

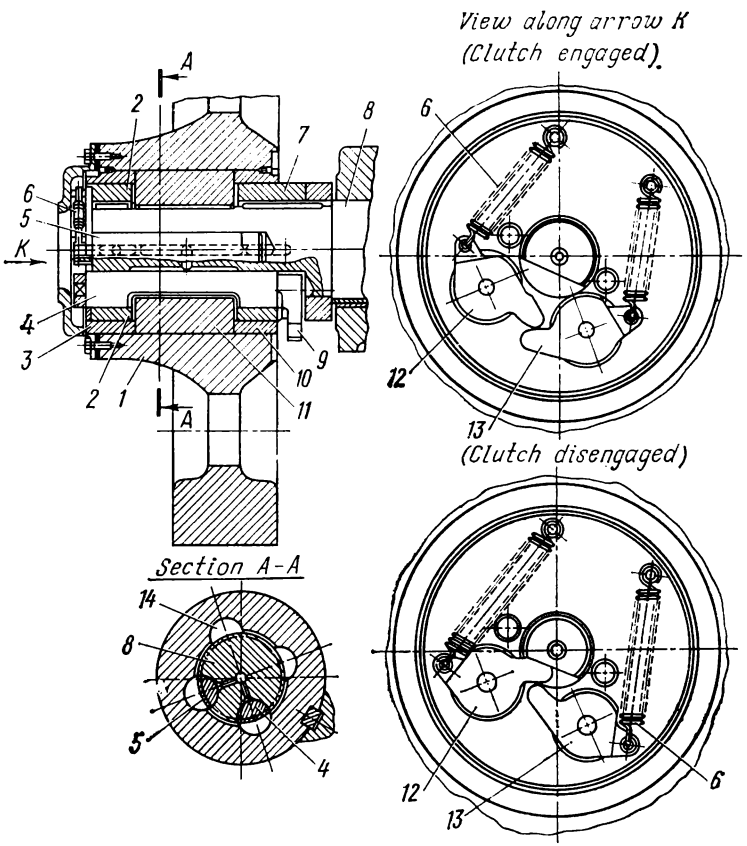


Fig. 117. Positive clutch with two rotating keys

If the press doubles, i.e. spontaneously starts the next stroke though the pedal is released, its clutch is defective and immediate stoppage and repair are necessary.

Positive clutches may be with rotating keys, dogs, etc.

Let us consider the design and operation of a positive clutch with two rotating keys (Fig. 117).

Two bronze bushings *3* and *10* are forced into flywheel *1* and rotate together with the latter on rings *2* and *7* which are mounted on crankshaft *8*. Steel bushing *11* with four slots *14* is also forced into the fly-

wheel. Main *4* and additional *5* rotating keys accommodated in two semicircular grooves of the crankshaft are interconnected by means of dogs *13* and *12*. Acted upon by springs *6* the dogs tend to turn the keys and move them out of the semicircular grooves. This is prevented by shank *9* held in place by the press engagement stop. Key *5* is prevented against turning by dog *13* of key *4*.

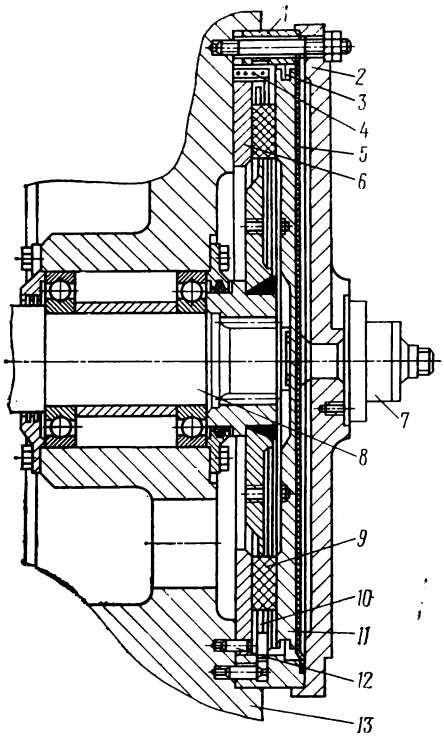


Fig. 118. Pneumatically-operated single-disk friction clutch

When the clutch is engaged, the stop is moved away, the keys get released and can couple the flywheel with the crankshaft. When the clutch is disengaged, the stop returns to the initial position to retain shank *9*. This clutch ensures automatic disengagement of the flywheel from the shaft with the slide being in the upper position when the press operates in single strokes even if the operator has forgotten to release the pedal. Besides, key *5* provides for reverse rotation of the crankshaft, which can be needed in adjustment.

The friction clutches connect the flywheel and the crankshaft owing to friction forces. They can engage the press at any position of the slide, ensure inching or stoppage of the latter in any position dictated by the operating or safety conditions. Such clutches are installed on almost all modern presses.

The disk friction clutches have one (single-disk) or several (multi-disk) sets of driving and driven friction disks. The former are connected to a continuously running flywheel, the latter to the crankshaft. When the clutch is engaged, the driven disks are pressed against the driving ones and torque from the flywheel is transmitted to the crankshaft or intermediate shaft by the forces of friction. On most occasions the disks are pressed with the aid of pneumatic devices. There are also friction clutches with a mechanical or hydraulic engagement.

The modern mechanical presses are mainly equipped with pneumatically-operated single-disk friction clutches (Fig. 118).

Clutch casing *1* and driving disk *6* are secured by means of bolts and pins *12* to the flywheel or gear *13* rotating continuously on the bearings of crankshaft *8* when the press electric motor is cut in. The crankshaft mounts stationary disk *10* with liners *9* made from special friction material "retinax".

To engage the clutch, compressed air is fed through supply head *7* to the cavity of cover *2*. The air pressure is imparted through diaphragm *5* to disk piston *11* meshed with clutch casing *1* by gearing *3*.

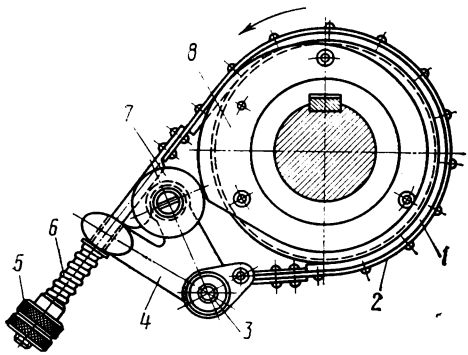


Fig. 119. Intermittent-action band brake

While moving, piston disk *11* presses friction liners *9* to driving disk *6*, thus transmitting torque from the flywheel or gear *13* to crankshaft *8*.

To disengage the clutch, compressed air supply is ceased and springs *4* force the disk piston away.

The press brakes serve to keep the slide in the TDC position when the clutch is disengaged. Modern mechanical presses are usually equipped with friction disk brakes. The old models and some small modern presses have band brakes.

Band brakes can be of a continuous-action and intermittent-action type. The former ensure braking of the slide in any position, the latter, in the TDC or other given position of the slide.

The continuous-action band brakes are disadvantageous in rapid wear of the band and additional friction losses.

The *intermittent-action band brake* (Fig. 119) includes brake drum *1*, cam disk *8* and brake band *2* with friction liners. One end of the brake band is secured by pin *3* to the press frame, the other, to lever *4* pivotally mounted on pin *3*. One end of lever *4* carries roller *7* running over the surface of cam disk *8*. When the press slide completes its stroke near the top dead centre, roller *7* is forced away by the projection of cam disk *8* installed on the crankshaft. While moving away, roller *7* deflects lever *4*, thus tensioning brake band *2*. After the press is engaged, cam disk *8* starts rotating with the crankshaft,

releases roller *7* and brake band *2* moves away from the brake drum. The brake force is adjusted by spring *6* the tension of which is set with the aid of nut *5*.

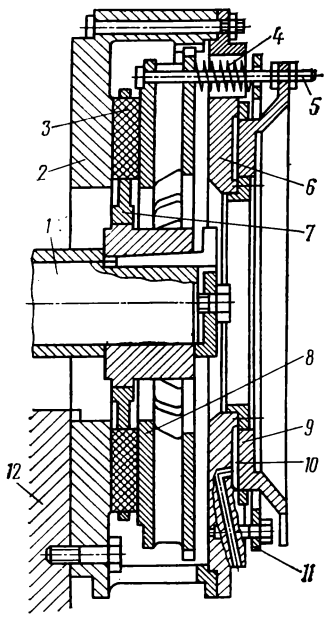


Fig. 120. Pneumatically-operated disk brake

1—drive shaft; *2*—brake casing; *3*—"retinax" liner; *4*—brake springs; *5*—bolts; *6*—cover; *7*—brake disk; *8*—pressure disk; *9*—piston; *10*—membrane; *11*—adjustment ring; *12*—frame

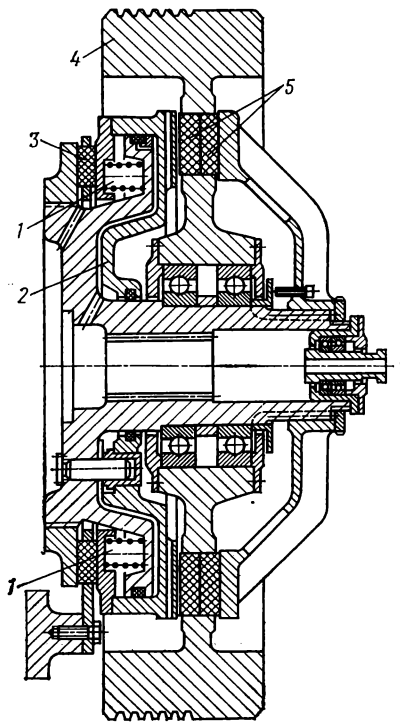


Fig. 121. Brake-and-clutch assembly

1—brake springs; *2*—piston; *3*—friction disk of a brake; *4*—flywheel; *5*—friction disks of a brake and clutch

The band is tensioned in the intermittent-action brake by a pneumatic cylinder which is controlled either automatically or manually.

The disk brakes operate similarly to the disk friction clutches and are interlocked with the latter.

Casing *2* of a disk friction brake (Fig. 120) is attached to frame *12*. Brake disk *7* with friction liners *3* made from "retinax" is secured to driving shaft *1* by a wedge key.

When the clutch is disengaged, brake springs *4* press friction liners *3* through pressure disk *8* to stationary casing *2*, thus braking shaft

1. When the clutch is engaged, compressed air moves piston *9* and pressure disk *8* fastened to the latter by bolts *5*. Springs *4* are compressed and the brake is released.

The brake springs are adjusted by means of ring *11* bolted to cover *6*.

Some mechanical presses are equipped with brake-and-clutch assemblies. Figure 121 shows the friction brake-and-clutch precluding si-

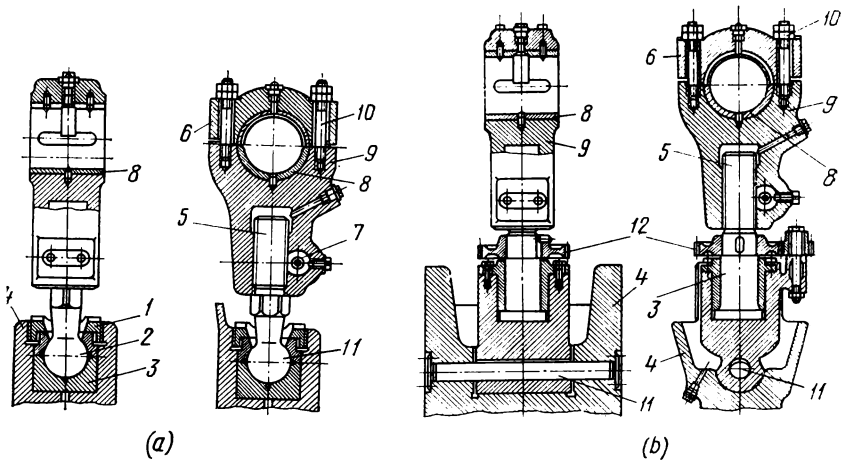


Fig. 122. Pitman-to-slide joint
(*a*) by a screw with a spherical head; (*b*) by a screw and cylindrical pin

multaneous operation of the clutch and brake. This considerably increases the reliability and life of the device.

Friction disks *5* of the clutch are mounted directly in flywheel *4*, and friction disk *3* of the brake with liners is rigidly fixed to the frame. When compressed air is supplied, piston *2* displaces, first releasing the brake and then engaging the clutch.

The pitman is connected to the slide by a screw with a spherical head, cylindrical pin or by means of plungers.

Pitman *9* (Fig. 122*a*) of a small press is connected to slide *4* by means of screw *5* with spherical head *2*. The pitman has bronze liner *8* whose inner surface slides over the crankshaft neck. Lid *6* of the pitman end is fixed by means of bolts *10*. Screw *5* is driven into the pitman body while its spherical head *2* rests on ball socket *3* of the insert of slide *4*.

The screw spherical head is retained in the slide by upper part *11* of the insert and nut *1*. The screw connection of the pitman and slide makes it possible to adjust the tool space height and install press tools of different heights. Screw *5* is fixed with locking device *7*.

In some larger presses, screw *5* is connected to slide *4* by means of pin (shaft) joint *11* (Fig. 122*b*). The tool space is adjusted in such presses with the aid of screw *5* turned by gear *12* which is driven from a separate electric motor.

In heavy presses, the pitman is often connected to the slide by means of one or more cylindrical plungers (see Fig. 114*b*). The plungers travel in special guides, which relieves the slide of lateral forces developed by the crank gear and ensures higher accuracy of the press operation and longer life for its guides.

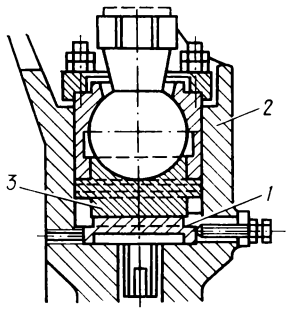


Fig. 123. Safety device with a shear-off plate
1—plate; *2*—slide; *3*—ball socket

To prevent lowering of the slide with the brake in failure and ensure more accurate pressworking, slide equilibrium devices are provided. These are usually pneumatic cylinders whose pistons are connected to the slide. When the slide lowers, the air in the cylinders is compressed and forced out into a receiving tank. When the slide rises, the air gets from the receiving tank under the piston and partly relieves the crankshaft of the force necessary for lifting the slide and the upper part of the tool. The equilibrium devices result in a more uniform travel of the slide and decreased wear of tools.

To preclude damage from overloading the presses are provided with safety devices limiting the working force on the slide or the torque on the crankshaft. A device limiting the working force on the slide is shown in Fig. 123. Plate *1* of a calibrated strength is arranged under ball socket *3* of slide *2*. Plate *1* is broken at overloading.

The second-type devices are provided with pins in the flywheel-clutch system, which are sheared off at overloading and release the clutch. The latter devices can be also so designed as to permit slipping of the driven friction clutch when the press is overloaded.

Some presses are equipped with hydraulic or hydropneumatic safety devices.

To eject stampings from the tool and hold down the bank, the presses are provided with the auxiliary power cylinders (cushions). The cushions are built in the bed or slide of the press. The presses may include pneumatic (Fig. 124*b*) or hydropneumatic cushions. The force developed by the cushions amounts to about 5-15 per cent of the rated press force, while the cushion travel is about a half of the press stroke. Heavy double- and quadruple-crank presses have several cushions.

To eject stampings from the tool, use is also made of spring-loaded knock-outs (Fig. 124*a*) or crossbars (Fig. 124*c*). Crossbar *5* is accom-

modated in the horizontal hole of slide *6*. When the latter moves upward, the crossbar is retained by stops *7* secured on the press frame and pushes rod *8* of the knock-out which, in turn, presses against stamping *9* and ejects it from the tool.

Modern presses are equipped with a centralized forced lubrication system. The system comprises a pump which feeds lubricant, lubricant feeders and distributors and delivery pipes. Grease is fed from a

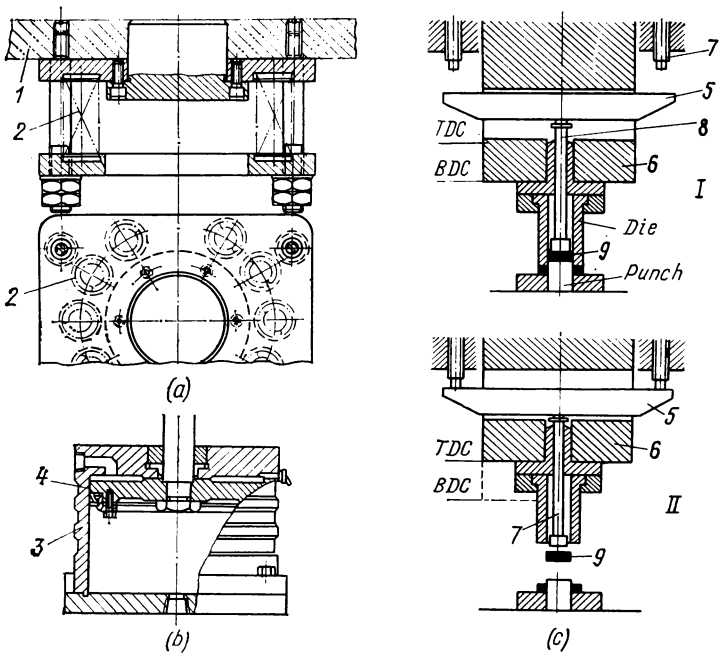


Fig. 124. Mechanical press knock-outs
(*a*) bottom spring-loaded; (*b*) bottom pneumatic; (*c*) top with a crossbar (*I*—end of pressing; *II*—ejection); *1*—press bed; *2*—springs; *3*—pneumatic cylinder; *4*—piston; *5*—knock-out bar; *6*—slide; *7*—stops; *8*—knock-out rod; *9*—stamping

central tank to the crankshaft bearings, slide guides, and pitman end. Oil is fed to the pitman screw, screw ball joint, clutch, brake and engagement mechanisms.

The press should be so lubricated that grease appears on the sides of friction surfaces, which indicates that the amount of lubricant in the unit is sufficient. The lubrication intervals and grades of lubricants to be used are specified in the lubrication chart. Prior to engaging the press, the operator should make sure that the pump is filled with lubricant and the friction parts of the press are lubricated.

Lubricant should be periodically delivered by means of the pump in the course of work.

The recent makes of medium and heavy mechanical presses are equipped with an oil lubrication system.

Modern mechanical presses are controlled by means of on/off buttons located on the frame or on a separate portable post, or with the aid of a control pedal. All these are electrical controls; they act

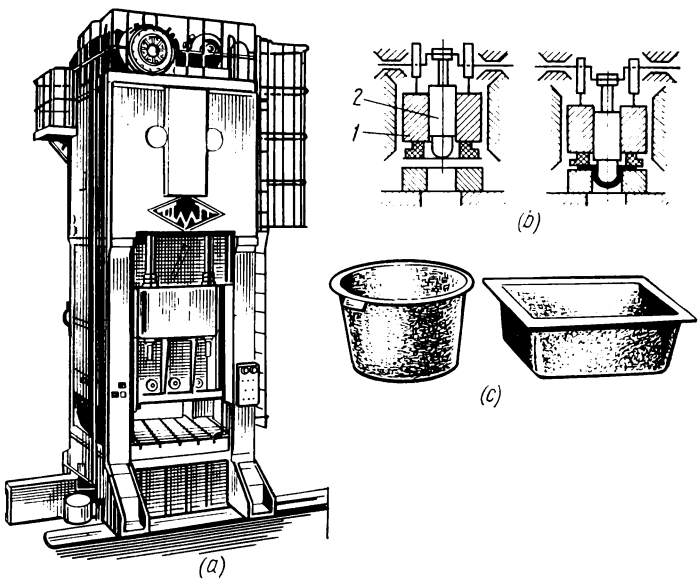


Fig. 125. Single-crank double-action press K5535
(*a*) general view; (*b*) operating diagram; (c) examples of stampings

upon a slide valve which admits air to or cuts it off from the pneumatic system of a friction clutch or brake.

The presses controlled by a pedal or buttons are provided with an interlock switch allowing only one system to be used for controlling the press. The pedal should be necessarily fitted with a guard to preclude inadvertent switching. Two-button (two-hand) switching is used to ensure safe operation, the buttons being arranged at such a distance from each other that they cannot be pushed by one hand simultaneously.

Double- and triple-action mechanical presses are intended to perform deep drawing. The double-action press (Fig. 125*a*) has two slides: outer slide *1* and inner slide *2* (Fig. 125*b*). The outer slide moves in the frame guides and clamps the blank, while the inner one moves in guides mounted on the outer slide and draws the articles (Fig. 125*c*).

The inner slide is driven directly from the crankshaft. The outer slide is set into motion by means of a gear train, crank and leverage.

The double-action presses have a longer stroke than the plain presses. The former are widely used in automotive industry.

Figure 125 shows press K5535 with a rated force of 315 tf which has a double-arm closed frame. The frame comprises two arms and a traverse integrated by four bracing bolts. The press is equipped with a single-disk friction clutch and brake. To eject stampings from the die, a hydropneumatic cushion is arranged inside the bed.

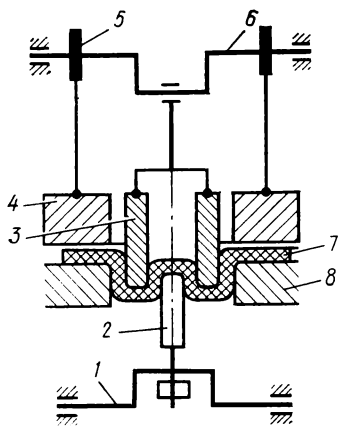


Fig. 126. Diagram of a triple-action mechanical press
1—lower crankshaft; *2*—lower slide; *3*—inner slide; *4*—outer slide; *5*—cams; *6*—upper crankshaft; *7*—workpiece; *8*—die

The press features a photo cell safety system and can be operated in the inching, automatic or single-stroke modes. It is controlled by push buttons. The triple-action presses (Fig. 126) have three slides. One of them is blankholder slide, while two others, the drawing ones moving in the opposite directions.

Coining knuckle-joint presses (Fig. 127*a*) are used for cold sizing, coining, straightening and other pressworking operations which require high forces with a short stroke of the slide. These presses can be also employed for cold extrusion. The slide is reciprocated by a mechanism consisting of a crank gear and a toggle (Fig. 127*b*). This mechanism provides for obtaining a considerable force by the end of the slide working stroke at relatively low torque of the drive shaft. The toggle is disposed inside the slide.

The press shown in Fig. 127 is rated for 1 000 tf and has a one-piece welded double-arm frame of increased rigidity. It is driven from a 40-kW electric motor via a V-belt transmission, a flywheel, a clutch, a geared shaft and a pair of eccentric helical gears. The press slide is counterbalanced by pneumatic cylinders arranged on the frame. The slide stroke is 170 mm. Knock-outs are installed in the bed and in the slide.

The clutch and the brake are of the single-disk friction type. The press is controlled by push-buttons from a remote console and has a photo cell protection of the tool space. The construction of the press provides for installing it on the base without special foundations or additional attachment.

Screw friction presses are used for drawing, bending, embossing,

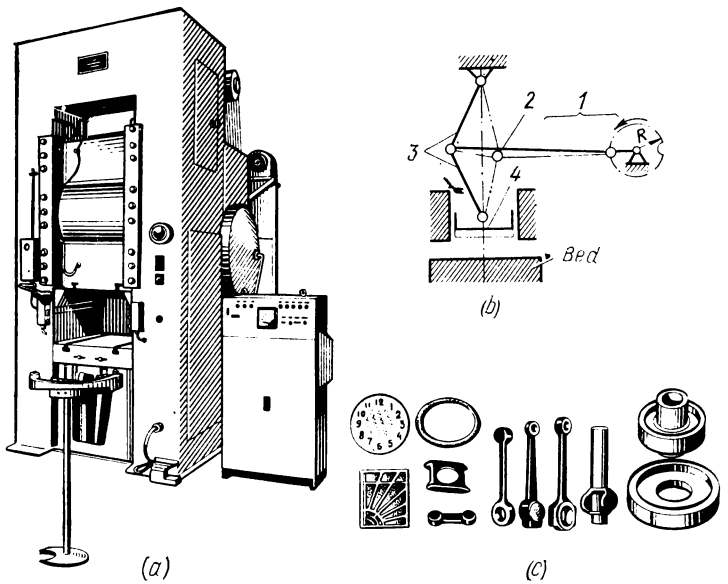


Fig. 127. Coining knuckle-joint press K8340
(*a*) general view; (*b*) operating diagram; (*c*) examples of stampings; *1*—crank gear; *2*—pitman; *3*—toggles; *4*—slide

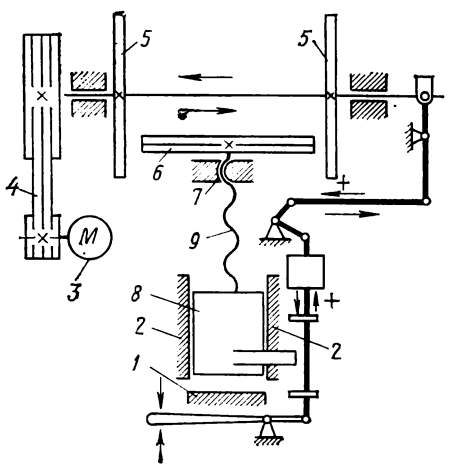


Fig. 128. Mechanical diagram of a screw friction press

straightening of sheet parts, heading, coining, sizing of three-dimensional parts, etc. (Fig. 127*c*).

Screw *9* (Fig. 128) of a screw friction press moves in stationary nut *7* secured in the frame. The upper end of the screw carries flywheel *6* which is arranged between disks *5* driven by electric motor *3* by means of V-belt drive *4*. Disks *5* are horizontally movable to be alternately pressed to flywheel *6* or moved away from it. The friction

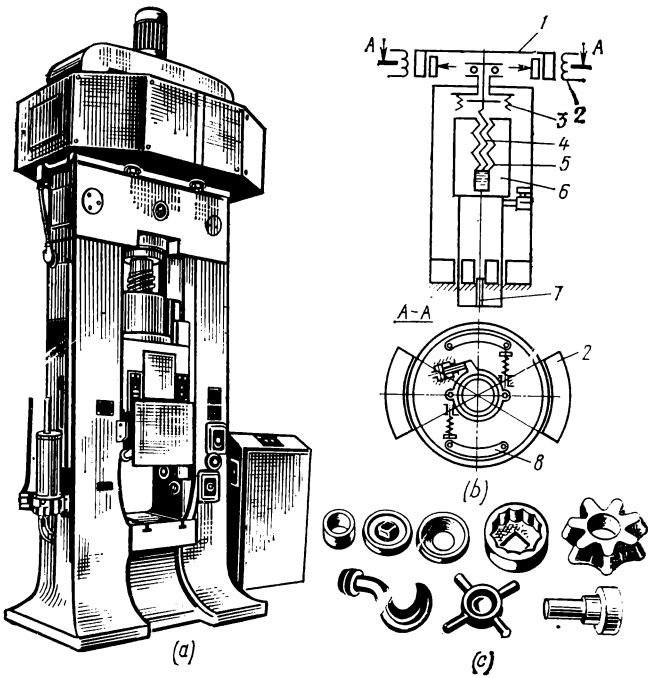


Fig. 129. Screw press with an arc-stator drive (*a*) general view of press ФБ1732 with a rated force of 160 tf; (*b*) operating diagram; (*c*) examples of stampings

forces appearing between the disks and the flywheel make the latter rotate. The direction of rotation of the flywheel, hence the direction of the screw movement (up or down) depends on which of the disks (the right-hand or left-hand one) is forced against the flywheel. Attached to the lower end of the screw is slide *8* which reciprocates with the latter in guides *2* of the frame. The tool is mounted on bed *1*.

Pressworking is accomplished on such presses by impacts at the expense of the energy accumulated by the rotating flywheel and screw, and also by the descending slide.

In modern screw presses the friction disks are replaced with an arc-stator drive. Flywheel *1* of such a press (Fig. 129) is accelerated by a three-phase induction motor with arc stators *2* (rather than annular stators as in conventional electric motors) arranged on frame *3*.

The flywheel doubles as the squirrel-cage rotor of an electric motor. The flywheel rotor rotates working screw *4* which is mated with nut *5* rigidly secured in slide *6* of the press. The rotation of screw *4* makes the slide with nut reciprocate. Stampings are ejected by knock-out *7*.

The flywheel and arc-stator drive are made as an independent unit mounted on the press. Brake *8* of the press is of a pneumatically-operated shoe type. The inner surface of the flywheel rim serves as a brake drum.

The mechanical knock-out is arranged in the bed and is driven from the press slide. To damp impacts applied by the slide to the upper traverse during upward stroke, shock absorbers are provided on the press arms.

The press has a split closed frame comprising a bed with arms and a traverse integrated by bracing studs. The bed with arms is a one-piece iron casting, while the traverse is cast from steel.

3. Hydraulic Presses

Hydraulic presses are used for drawing and bending sheet parts, direct and inverse extrusion of three-dimensional blanks and other cold pressworking operations.

Hydraulic presses have a number of advantages over the mechanical ones: it is possible to create rather easily high working forces; the force remains constant at any point of the slide stroke; the strokes can be very long; the presses withstand great overloads; the speed of the working tool movement remains invariable and it is possible to adjust it; the stroke is adjustable; the operation is noiseless; an article can be kept under pressure for a certain period of time.

However, the hydraulic presses are more expensive and less productive than the mechanical ones.

Owing to a considerable rise in their speed of action achieved in recent years, the hydraulic presses are successfully ousting the mechanical ones from the pressworking shops.

The hydraulic presses (see Fig. 130*a*) are based in their operation on Pascal's law. If force F_1 is applied to piston A, liquid pressure $p = F_1/a_1$ will be created under the piston, which according to Pascal's law, is transmitted uniformly in all directions. Therefore, force $F_2 = pa_2$ or $F_2 = F_1a_2/a_1$ will act upon piston B. Thus force F_2 exceeds force F_1 by so many times as area a_2 exceeds area a_1.

The construction of a hydraulic press is diagrammatically shown in Fig. 130*b*. The press comprises upper *4* and lower *7* traverses (crossbars) interconnected by posts *5*. Upper traverse *4* mounts working cylinder *2* with plunger *3*. Working plunger *3* is connected to ram *6*. Ram (crossbar) *6* is guided by posts *5*. Plunger *3* moves the

ram only downwards; the upward motion is effected by return (lift) cylinders *8* with plungers *9*.

There are down-stroke hydraulic presses in which the working cylinders are arranged above the bed, and up-stroke ones, in which the latter locate below the bed level. The up-stroke hydraulic presses may have no return cylinders, since the ram returns to the initial position by gravity. The bottom arrangement of the working cylinders provides for considerably decreasing the press height above the floor level.

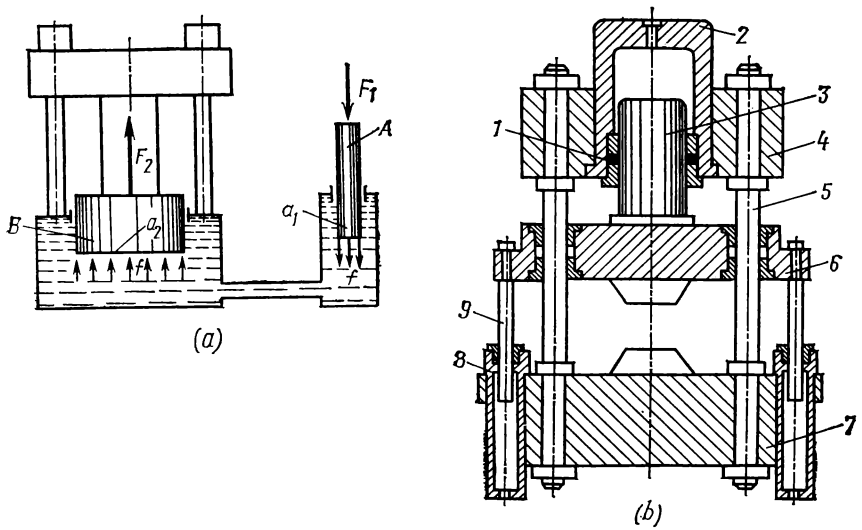


Fig. 130. Diagram (*a*) and construction (*b*) of a hydraulic press
1—seal; *2*—working cylinder; *3*—working cylinder plunger; *4*—upper stationary crossbar; *5*—posts; *6*—ram; *7*—lower stationary crossbar; *8*—return cylinder; *9*—return plunger

As regards the operating principle, there are single-action presses having one ram, double-action presses with two rams — an outer blankholding and inner forming one; and triple-action presses which include three rams — one blankholding and two forming rams moving in the opposite directions.

Depending on the construction of the frame, the hydraulic presses, similarly to the mechanical ones, are divided into single- and double-arm presses. In the double-arm hydraulic presses shown in Figs. 132 and 133 the slide moves in the guides. Another type is pillar presses (Fig. 130*b*, Fig. 131) whose ram moves along the guide posts interconnecting the upper and lower stationary crossbars. Such presses usually include four posts.

To decrease the mass of presses, pre-stressed frames with the use of high-strength band or wire are utilized. Frames of some heavy presses are made from reinforced concrete.

Depending on the drive used, pump-and-accumulator presses and individual drive presses are distinguished.

The working fluids used in hydraulic presses are mineral oil, water and aqueous emulsion being a 2 to 3 per cent solution of emulsifier in water. The emulsifier includes mineral oil, oleic acid, sodium hydroxide. Water used without emulsifier causes corrosion of cylinders, pipelines and valves and increases wear of hydraulic devices.

Presses are driven by crank plunger pumps (for aqueous emulsions) and rotary plunger, gear and other pumps (for mineral oil).

During operation of the press with a pump and accumulator plant, the hydraulic accumulator installed between the press and the pump releases the accumulated high-pressure fluid during a short-time working stroke and then again accumulates the fluid. The accumulator ensures a high speed of the ram and the required force when using pumps and motors of relatively low power since the working stroke force corresponds to the fluid pressure in the accumulator.

The *press with a pump and accumulator plant* (Fig. 131) comprises stationary lower crossbar *4* and upper crossbar *8* interconnected by four posts *5*. Stationary upper crossbar *8* carries working cylinder *9* and return cylinders *12* with working *7* and return *11* plungers, respectively. Working plunger *7* is connected to ram *6* which mounts the upper half of tool *3*. Lower half *2* of the tool is installed on movable bed *1*.

The return cylinder plungers are connected with crossbar *10* which is coupled with ram *6* by means of rods *13*.

The operation cycle of a hydraulic press comprises an idle stroke of the ram lasting till the tool upper half contacts the metal to be worked, a working stroke during which the metal is deformed and a return stroke, i.e. upward movement of the crossbar.

The idle stroke is effected with the use of low-pressure fluid fed to cylinder *9* and a system of pipelines from make-up tank *14* through make-up valve *35*.

The working stroke is performed under the action of high-pressure fluid. The high pressure is created by pump *21* which supplies the fluid via pipeline *22* to hydraulic accumulator *32*. The fluid pressure is maintained in the accumulator by compressed air fed from bottles *34*. The bottles are charged from compressor *20* through pipeline *33*.

The press is controlled by handle *23* with cams *24* and *26*. A turn of the handle opens or closes valves *25*, *27*, *28*, *30*. To perform the working stroke, handle *23* is turned to close valves *28* and *30* and to open valves *25* and *27*. High-pressure fluid is delivered through make-up valve *35* to pipeline *15* and then to working cylinder *9*.

When ram *6* is lifted, valves *28* and *30* are opened and valves *25* and *27* are closed. Now high-pressure fluid flows through pipeline *16* and acts upon piston *36* with rod *37* moving them rightward, thereby shutting off supply of high-pressure fluid to working cylinder *9*. High-pressure fluid is simultaneously supplied via pipeline *29* to return cylinders *12* and ram *6* rises.

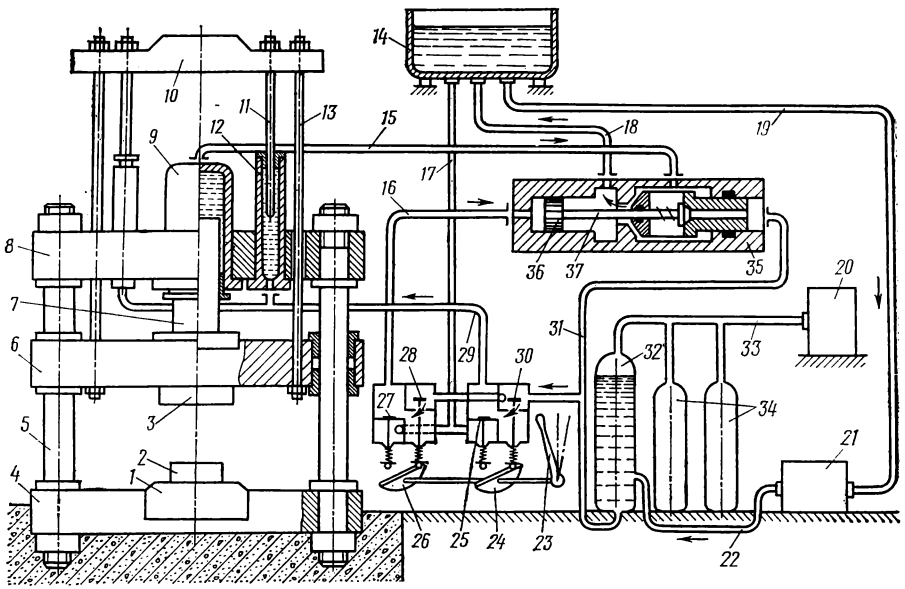


Fig. 131. Schematic diagram of a hydraulic press with a pump and an accumulator plant

1—movable bed; *2*—lower half of tool; *3*—upper half of tool; *4*—lower stationary crossbar; *5*—posts; *6*—ram; *7*—working cylinder plunger; *8*—upper stationary crossbar; *9*—working cylinder; *10*—crossbar; *11*—return plunger; *12*—return cylinder; *13*—rods; *14*—make-up tank; *15, 16, 17, 18, 19, 22, 29, 31*—pipelines; *20*—compressor; *21*—high-pressure pump; *23*—handle; *24, 26*—cams; *25, 27, 28, 30*—distributor valves; *32*—hydraulic accumulator; *33*—air pipeline; *34*—air bottles; *35*—make-up valve; *36*—piston; *37*—rod

It should be noted that the efficiency of the pump and accumulator plant is not high and the control system is more complex if compared with individual drives.

In hydraulic presses with individual drives, working fluid is fed to the press cylinders directly from one or several pumps. The individual drive is compact and simple to control.

The pumps and electric motors are so selected as to ensure the maximum speeds of the ram and maximum pressing force. If high speeds and forces are needed, fairly powerful pumps and motors must be installed. However, maximum speed or power modes are usually

intermittent so that the power of the pumps and motors is not utilized fully.

To increase the efficiency of a hydraulic press plant, use is made of boosters. These are devices consisting of two different-diameter cylinders. The larger-diameter cylinder receives pressure fluid from a pump or accumulator, while the smaller-diameter cylinder supplies

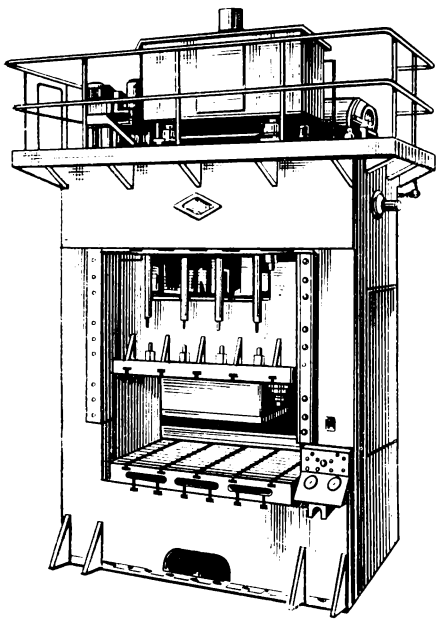


Fig. 132. Sheet stamping hydraulic frame-type single-action press П135 with a rated force of 630 tf

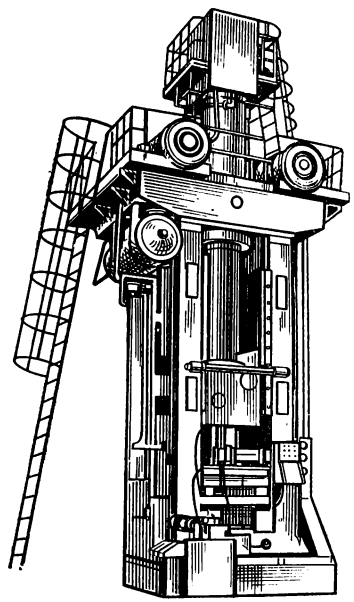


Fig. 133. Hydraulic drawing press ПА7834А with a rated force of 250 tf

high pressure fluid to the press. The booster pressure rise is equal to the ratio between the areas of the larger and smaller cylinder plungers.

As regards their purpose, the hydraulic presses are divided into multi-purpose and special ones. The latter include presses for deep drawing, cold extrusion, scrap briquetting, bending, rubber-pad stamping, fluid stamping, etc.

A *sheet stamping hydraulic press* (Fig. 132) is designed for performing various pressworking operations such as bending, drawing, flanging, etc. The double-arm frame comprises a bed, two arms and upper crossbar integrated by means of four bracing bolts.

The press has an individual drive comprising a rotary plunger pump with a throughput of 200 l/min driven from a 75-kW electric motor.

The press ram is actuated by three hydraulic cylinders mounted on the upper crossbar. The ram travel is 750 mm. The bed accommodates a hydraulic knock-out.

A *drawing hydraulic press* (Fig. 133) is intended for deep drawing of articles. The ram travel is 1 500 mm. The individual hydraulic drive is mounted on the upper crossbar. Disposed inside the plunger of the main cylinder is a cylinder of the ram quick stroke, which increases the ram speed to 35 m/min. The press is equipped with a knock-out and a tong hold mechanism for feeding blanks into the tool space. Both of them are hydraulically-operated.

4. Automatic Presses

Automatic presses are widely used in the mass production. These for sheet stamping include primarily multi-station presses and automatic up-stroke presses. In cold die forging the automatic presses

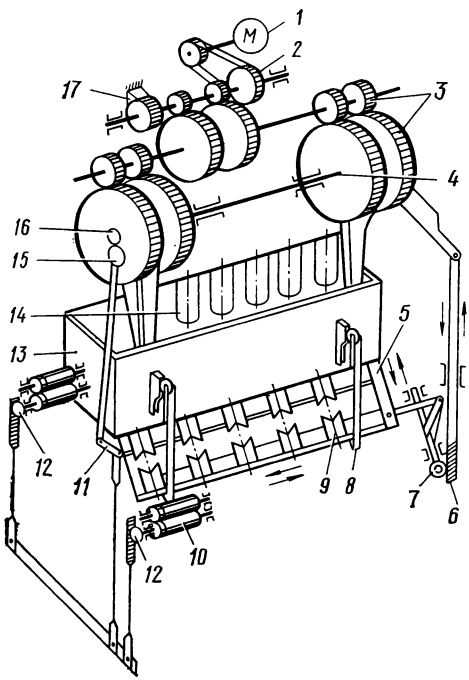


Fig. 134. Mechanical diagram of a multi-station automatic press

1—electric motor; *2*—clutch; *3*, *16*—gearings; *4*—double-throw crankshaft; *5*—bars; *6*, *11*—rods; *7*—rack-and-lever mechanism; *8*—lever-wedge joint; *9*—grippers; *10*—feeding rolls; *12*—rack-and-ratchet mechanism; *13*—ram; *14*—chuck; *15*—crank; *17*—brake

are used for making various fasteners (bolts, nuts, rivets, screws, nails), balls, rollers, rings, coiling springs, etc.

Sheet stamping multi-station presses are designed for consecutive stamping of articles from a strip, band or blanks with automatic

transfer between stations. These presses can perform several operations during one stroke of the slide: blanking, drawing, hole punching, trimming, etc.

The blank is worked in simple tools arranged in succession. The required number of knock-outs is installed in the ram and in the bed of the press to eject workpieces from the dies.

Figure 134 shows a mechanical diagram of a multi-station automatic press, Fig. 135*a*, *b* — automatic press A6134A with a rated force of 250 tf.

The automatic press operates as follows (see Fig. 134). Torque from electric motor *1* is imparted via a V-belt drive to an intermediate shaft which carries clutch *2* and brake *17*. The intermediate shaft transmits the torque by gearing *3* to double-throw crankshaft *4* whose rotation is converted by two pitmans into reciprocation of ram *13*.

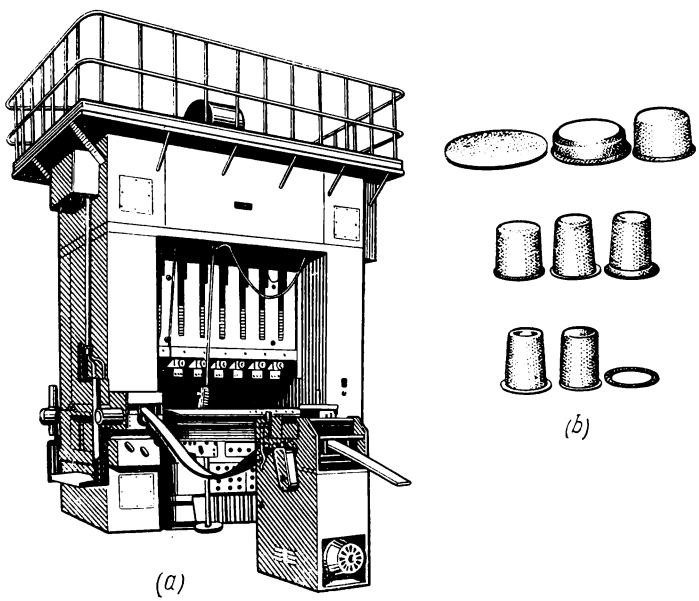


Fig. 135. Sheet stamping multi-station automatic press A6134A
(*a*) general view; (*b*) examples **of** stampings

The strip is fed to the first pressing station by feeding rolls *10* rotated from the crankshaft by gearing *16*, crank *15*, rod *11* and rack-and-ratchet mechanism *12*.

Workpieces are transferred between the stations by means of an intermittent feeding mechanism with bars *5* and grippers *9*. The bars

are moved by means of rod *6* and rack-and-lever mechanism *7*. During the working stroke of the press, lever-wedge joint *8* makes grippers *9* open.

The upper parts of the tool are secured in chucks *14* adjustable in height.

The automatic presses are equipped with uncoilers. The strip scrap is either cut by special shears or wound on coilers.

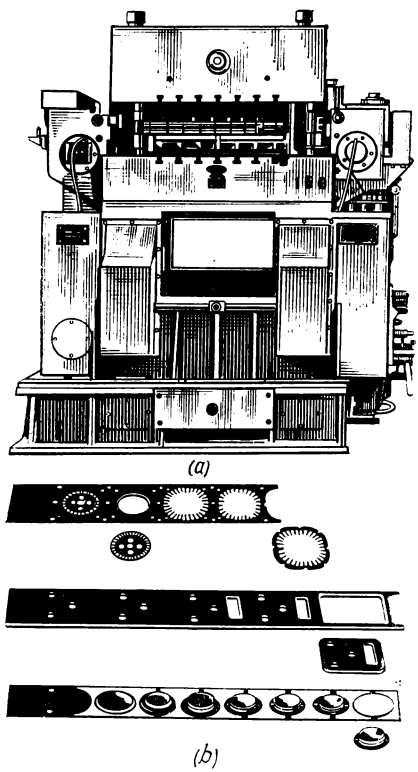


Fig. 136. Sheet stamping upstroke automatic press AA6232
(*a*) general view; (*b*) examples of stampings

The automatic press shown in Fig. 135 has eight pressing stations and a ram stroke of 320 mm. It performs 28 strokes per minute and handles strips up to 300 mm wide.

The multi-station presses are designed for stamping bulb holders, ball bearing cages, small automobile parts, etc.

In addition to gripper feeds, the multi-station automatic presses use other feeding devices, i.e. roll, tong hold, etc. Owing to high productivity (up to several thousands of parts per hour), one multi-station automatic machine can replace several common presses.

To make small electrical equipment parts such as stator and rotor laminations, cores, etc., *sheet stamping automatic presses* with a bottom drive are widely used (Fig. 136*a*, *b*). The crank gear of the press is arranged below the bed level. It is driven from a dc motor with variable speed control. The motion from the eccentric shaft of the press is transmitted to the crossbar. The lower crossbar is arranged under the bed, the upper one (ram) over the bed. The crossbars are interconnected by four cylindrical posts. The press is equipped with two-side roll feeders. The upper crossbar (ram) accommodates devices for adjusting the tool space and lifting the upper rolls of the feed, and also spring-loaded knock-outs.

The clutch and brake of the press are of the pneumatically-

operated disk type. The movable parts of the press are counterbalanced by pneumatic cylinders.

Uncoilers and coilers are provided for coil strip stamping. The strip scrap can be cut by special shears driven from the roll feed.

The presses with a bottom drive can have a rated force of from 2.5 to 160 tf and up to 1 000 strokes per minute (low-force models); the stroke is from 8 to 75 mm.

The production of cold pressworking equipment with numerical control has recently increased both in this country and abroad. The NC systems are installed on hydraulic sheet bending presses, pipe bending machines and especially piercing mechanical presses.

The *piercing numerically-controlled presses* are used for making holes in electric and radio equipment circuit boards. The press bed mounts a carriage which displaces the blank. Punches and dies are secured in the upper and lower disks of the turret respectively. The press turret has about 30 stations and is rotated from a separate motor. Rotation of the turret and displacement of the blank are performed according to a particular program inserted by means of standard punched cards.

Cold heading machines (or headers) are special horizontal mechanical presses. There are single-station and multi-station headers. The single-station headers are the most popular ones; they can be single-strike or double-strike, depending on the number of steps accomplished in one die with automatic change of punches. By the construction of the die, one-piece die and split-die headers are distinguished.

The mechanical diagram of a single-strike automatic header with a one-piece die is shown in Fig. 137. The header is intended to make heads of bolts, screws, rivets. It is driven from electric motor *11* through a pair of gears *9*, *10* and crankshaft *12*. Bar *1* is fed by grooved rollers *17* to shearing die *15*. The rollers are actuated by eccentric *8* through ratchet gear *2*.

When slide *16* of the shearing mechanism moves leftward, the roller of blade rod *14* slips along the groove of the cam and shifts the rod vertically upward. The blade secured on the rod cuts off the blank and transfers it to the heading station in die *5*. The head is upset by punch *13* during one stroke of ram *6*. The headed piece is ejected from the die by knock-out *4* when rocker *3* turns under the action of rod *7* which is driven from the cam mechanism linked with crankshaft *12*.

The multi-station automatic headers are widely used for making parts of more intricate shape such as shaped nuts, spherical pins with hollow and solid heads, bolts, screws, etc. In such machines, the blank is worked with one stroke of the ram in each station and is then automatically transferred to the next one.

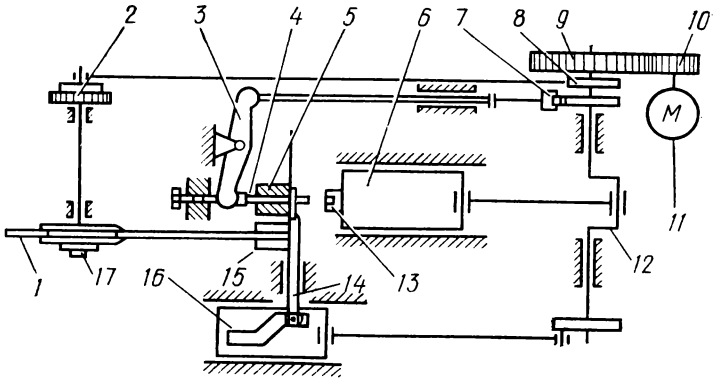


Fig. 137. Mechanical diagram of a single-strike automatic header with a one-piece die

1—bar; *2*—ratchet gear; *3*—rocker; *4*—knock-out; *5*—die; *6*—heading ram; *7*—roller; *8*—cam; *9*, *10*—gears; *11*—electric motor; *12*—crankshaft; *13*—punch; *14*—rod with a cut-off blade; *15*—cut-off die; *16*—shearing mechanism slide; *17*—grooved rollers

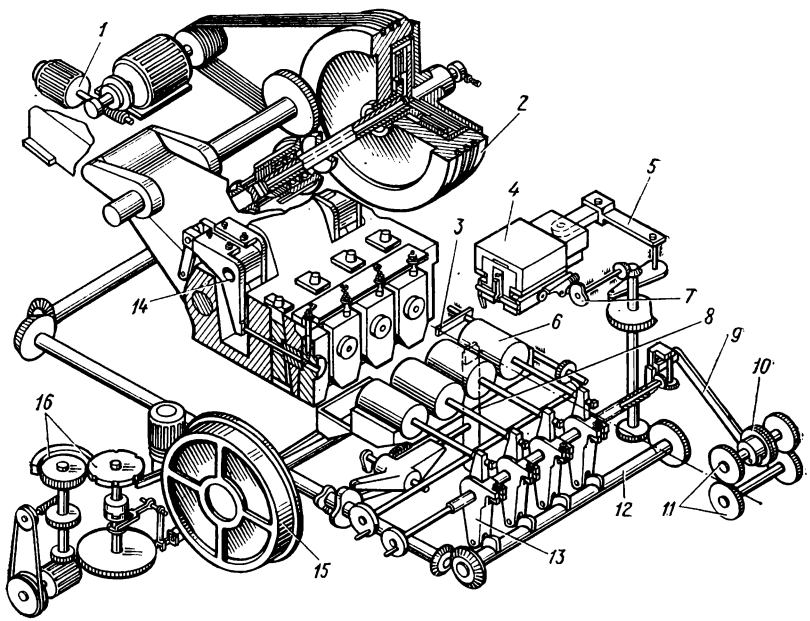


Fig. 138. Mechanical diagram of a multi-station automatic header

1—miniature drive motor (with reduction gear); *2*—flywheel with a friction clutch; *3*—adjustable stop; *4*—transfer mechanism carriage; *5*—transfer mechanism drive; *6*—die block; *7*—tong opening mechanism; *8*—shearing mechanism; *9*—feed mechanism drive; *10*—overrunning clutch; *11*—feed rollers; *12*—cam distribution shaft; *13*—die knock-out mechanism; *14*—punch knock-out mechanism; *15*—bin of a thread rolling device; *16*—thread rolling device

The mechanical diagram of a multi-station heading machine is shown in Fig. 138. The header is designed for manufacturing finished bolts, including thread rolling.

A cold drawn stock in coils (not shown) is fed by rollers *11* up to stop *3*. Shearing mechanism *8* cuts a measured blank which is transferred to the first upsetting station of die block *6*.

The blank transfer is effected by a transfer mechanism mounted on carriage *4*. The blanks are ejected from the dies by means of the studs of knock-out device *13* which is actuated by distribution cam shaft *12*. The headed bolts are automatically supplied to bin *15* of thread rolling device *16*.

The header is driven by an electric motor. Miniature drive motor *1* serves to drive the header mechanisms in the course of adjustment. The machine is equipped with mechanism *14* for ejecting parts from punches, which widens its sphere of application.

The automatic headers are also used for making balls, rollers, chains, coiling various springs, bending workpieces, etc.

5. Servicing and Accuracy Checks

Trouble-free, economical and safe operation of the pressworking equipment can be ensured only by proper maintenance. Before the work, a press must be put in order, i.e. all unnecessary objects removed from it, the friction surfaces lubricated by means of an oil pump or hand oiler. In the course of work, lubrication should be performed according to the lubrication chart.

On presses with electropneumatic switching, condensate should be drained from the pneumatic systems, supply of compressed air switched on, its pressure checked and its flow rate to the clutch and knock-outs adjusted. If a press has pneumatic equilibrium cylinders, they should be filled with compressed air.

After this the operator must check the condition of the guard and safety devices, and see if the tool is properly and reliably secured. If there is no tool on the press, it must be installed and adjusted (see Chapter XI). Before installing the tool or beginning the work, it is good to check the press in idling.

After the work is completed, the press and the working station should be put in order.

The accuracy of press operation and wear of its parts are periodically checked according to the schedule elaborated by the shop mechanical engineer. These checks are usually combined with adjustment of all its devices and mechanisms, tightening of bolts, nuts, bearings, etc.

This work may be also performed when requested by the operator or foreman, if faults have been detected in press operation.

A press must be checked and adjusted after its installation (even if it is new), or after it has been transferred to another place or repaired.

If the accuracy of the press does not conform to the specifications, its work will be faulty, the tools will wear quicker and breaking of the tools or the press itself may result.

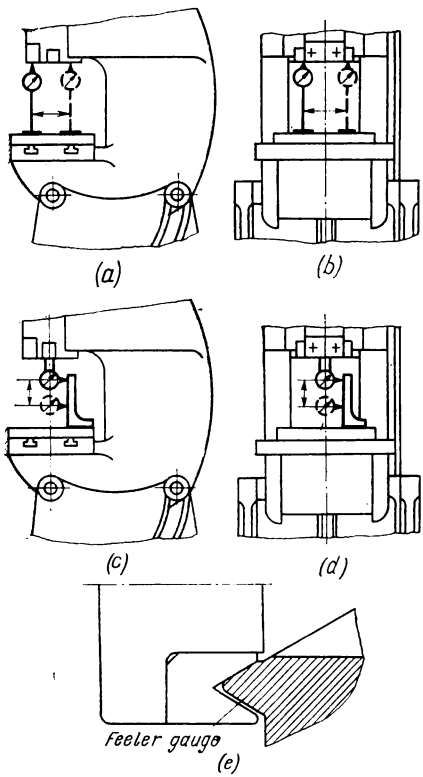


Fig. 139. Methods of checking press accuracy

(*a*, *b*) checking parallelism of the bed or bolster plate surface and the bottom surface of a slide (ram); (*c*, *d*) checking perpendicularity of the slide stroke to the bed or bolster plate surface; (*e*) checking clearances between the slide and guides (with a feeler gauge)

The procedures for checkout of the press manufacturing and assembly accuracy are outlined in the State Standards. The accuracy standards are established depending on the type and size of the press. Accuracy checks include checking the flatness and parallelism of the bed and bottom face of the slide (ram), perpendicularity of the slide stroke to the bed plane, axial and radial play of the flywheel, etc. (Fig. 139*a* to *e*).

The bed plane is the datum surface for the main accuracy checks of the press.

The flatness of the bed and slide bottom face is checked with the aid of a straight edge and a feeler gauge. The straight edge is applied to the surface to be checked and the gap between the straight edge and the bed (or slide) is measured with a feeler gauge.

The straight edge is applied in different directions. The gaps measured with feeler gauge should not exceed the specified limits. No convexity of the surface is allowed.

The perpendicularity of the slide stroke to the bed plane is usually checked using an indicator, gauge blocks and try squares.

The main document of a press is its certificate which contains the name, type, model and designation of the press, its manufacturer, the year of manufacture, place of installation, basic specifications, mechanical diagram, sketches of main units, the curve of the allo-

wable force on the slide and some other data. The specifications of a mechanical press include a rated force, the maximum and minimum strokes of the slide, the number of strokes per minute, pitman length adjustment, shutheight, etc. As an example, let us consider the specifications of single-action open press КД-1424, shown in Fig. 110.

Specifications

Rated force, tf	25
Adjustable stroke of slide, mm	5-65
Number of strokes per minute	120
Bed size, mm	500 × 340
Gap depth (distance from slide axis to frame), mm	190
Maximum shutheight at maximum stroke, mm:	
with bed in upper position	180
with bed in lower position	450
Maximum distance between horn hole axis and slide in BDC with maximum stroke, mm	210
Pitman length adjustment, mm	55
Bolster thickness, mm	50
Electric motor power, kW	2.7
Overall dimensions, mm:	
plan	1 170 × 1 200
height above floor level	2 145
Mass, t	2.8

In addition to the certificate, the manufacturer furnishes the press operating manual. This document contains information on the purpose and sphere of application of the press, its foundation, mounting and installation. Besides, the manual includes a schematic circuit diagram, lubrication chart, adjustment, set-up and start practices, safety precautions, daily care, troubleshooting procedures.

The press certificates have sections for making entries on the repairs performed and results of accuracy checks carried out after the repair.

6. Mechanization and Automation of Pressworking

Mechanization and automation of pressworking operations is one of the main ways to increased labour productivity, complete utilization of the equipment and high technoeconomical efficiency of production.

Automation and mechanization decrease labour input and production costs of articles, considerably facilitate work and ensure labour safety.

Mechanization is a complete or partial substitution of physical labour of a man with operation of machines, mechanisms, devices. If the operator not only controls the machine but also performs some steps of the operation manually, the mechanization is termed part-scale. An example of the part-scale mechanization is the use

of devices with manual loading but with power feed of blanks into the tool area. If the entire production operation is accomplished by the machine, while the operator only controls it, the mechanization is called integrated or full-scale. An example of full-scale mechanization is positioning of the tool on the press bed with the aid of a manipulator controlled by the worker.

Automated machines are those which operate according to a preset program for feeding the blanks to the tool, pressing, ejecting workpieces and scrap, while the worker or setter-up only supervises their operation; multi-station automatic machines make an example.

The integrated mechanization and automation offer the best results. These involve mechanization or automation of all the production and auxiliary operations throughout the production line, sections or shop. The examples are automatic transfer lines for the production of automobile parts, door hinges, etc., and also automated workshop sections operating for whole shifts (mostly night shifts) without attendance of a man.

Mechanization and automation always ensure a considerable rise in labour productivity owing to a more complete utilization of machine capacity. For instance, when making medium-size parts on a press with a speed of 60 strokes per minute and manual feeding of blanks, the operator manages to feed from 10 to 12 blanks per minute into the tool area so that the press capacity is used only for 15-20 per cent. By mechanizing the feed, the number of blanks can be increased by approximately 2-2.5 times. The capacity of an automatic press is used almost completely at separate time periods or for 75-80 per cent and more per shift (a part of time is spent for adjustment, replacement of tools, etc.). Besides, mechanization considerably increases pressworking safety, while automation practically rules out traumatic injuries.

The mechanization and automation of blank feed, workpiece and scrap ejection are given first priority in pressworking. In the case of the integrated mechanization or automation of transfer lines or shops, auxiliary and finishing operations are also mechanized and automated (transfer of preforms from one press to another, heat treatment, pickling, washing, painting, quality control).

Such operations as stacking and packing of parts, transfer and processing of scrap, etc. are also subject to automation. Besides, the automatic transfer lines can ensure accumulation of inter-operation stock of preforms and feeding of them to a succeeding machine if the upstream machine of the line fails for some reason.

Modern mechanization and automation facilities include monitoring and interlock devices which supervise automatic production and auxiliary operations and immediately stop a machine or transfer line in the case of malfunctions, incorrect feed or absence of blanks, appearance of defective workpieces, breakdown, etc. These devices

can be electric, electronic, photoelectric, or with radioactive isotope detectors.

The stock feeding mechanisms can be constructionally combined with the press tool or designed as separate units. In the former case, various tong, hook, tong-roller and other built-in feeders are used to automate feeding in strip metal stamping.

Hook *1* (Fig. 140) of one of *hook feeds* of a press tool is secured on pivot *2* of rocker *3*. The rocker swings on axle *4* which is arranged on upright *5* mounted on die block *10*. The swing of rocker *3* is limited by bolt *6* intended to adjust the feed pitch. Rocker *3* which shifts hook *1* turns when pushed by roller *9* which is secured with holder *7* to punch holder *8*.

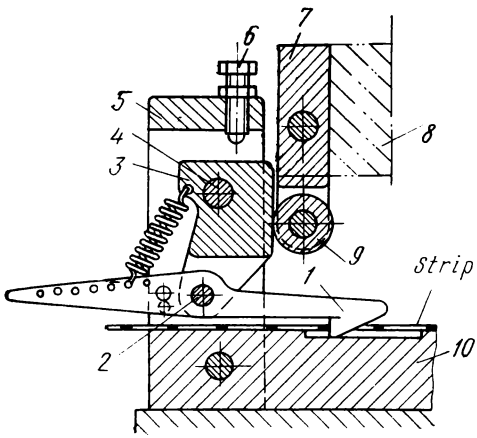


Fig. 140. Hook feed for strip stock

When the upper tool rises, rocker *3* is turned by the spring counterclockwise and moves the hook rightward. When the slide moves down, roller *9* returns the rocker to the initial position before the blank forming is started. Now lever *3* moves clockwise, the hook engages the next bridge of the strip and shifts it leftward through the feed pitch. The strip is finally fixed in place by the tool guide pins which enter the holes already pierced in the strip.

Hook feeds can be actuated by a lever, a hinged leverage, wedges, etc. They can be used for feeding metal strips from 30 to 300 mm wide and a feed pitch of 10-50 mm. The feed accuracy is from ± 0.2 to ± 0.5 mm.

The *tong feed devices* are designed with gripping planks, cams, rollers, catches, etc. They can be actuated by wedges, levers, etc. The tong feed device (Fig. 141*a*, *b*) is actuated by the upper half of the tool and can be used for feeding strips up to 100 mm wide at a feed pitch of up to 40 mm and accuracy of up to $\pm$ 0.1 mm. Base *1* is mounted on die shoe *13*. When the upper half of the tool moves upward, carriage *7* travels towards the tool area and moves the strip held by catch *10*. The carriage is moved by balancing lever *3* which is turned by means of sliding block *2* connected by rod *4* to punch holder *6*.

When the upper half of the tool moves downward, the punch enters the metal and holds the strip in place, striker *5* presses against

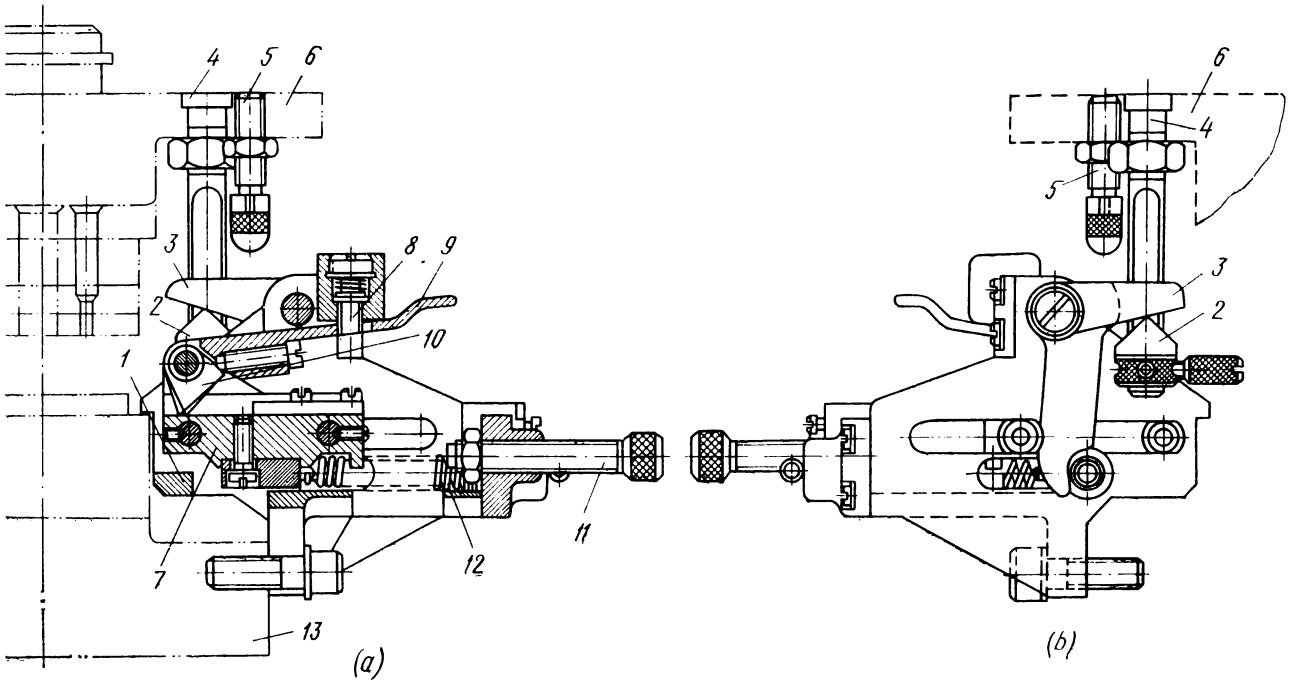


Fig. 141. Tong feed for strip stock
(*a*) general view; (*b*) rear view

lever *9* with retaining pin *8*. This releases catch *10* and the carriage is returned by spring *12* to the initial position. During the feed motion the springs are extended. The carriage travel is regulated by stop screw *11*.

In the *roller wedge feed* (Fig. 142) the strip is gripped between two pairs of feed rollers *2* mounted in movable carriage *3*. The feed mo-

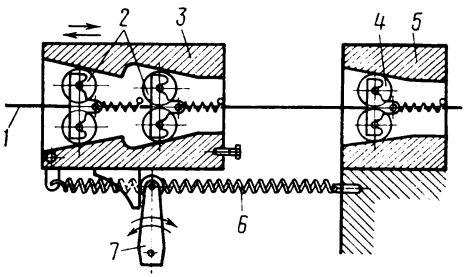


Fig. 142. Roller wedge feed for strip stock

tion of the carriage is effected from the crankshaft through a system of rods and levers the last of which, *7*, is shown in the figure. During the feed motion of carriage *3*, feed rollers *2*, arranged in the seats of the carriage, grip strip *1* and feed it through a pre-set pitch. The car-

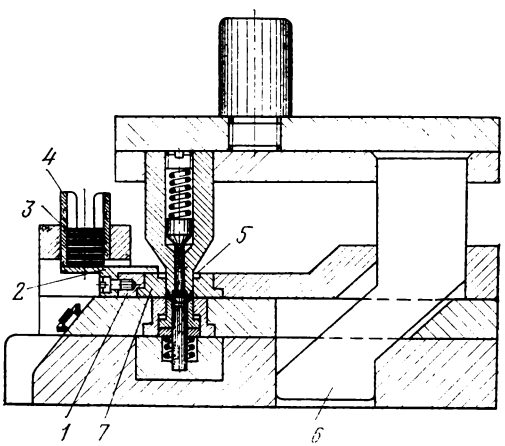


Fig. 143. Tool with gate feed

riage is returned by springs *6*. During the return stroke, the rollers *2* release the strip, while braking rollers *4* mounted on fixed carriage *5* grip it to preclude its backward motion.

Feeding of individual blanks is automated with the use of gate, dial and grab feeds.

In a simple tool with a *gate feed* (Fig. 143), blanks *3* are placed in magazine *4*. The blanks are fed into the tool area by gate *1* driven

by double-sided wedge *6* secured to the upper half of the tool. When the upper half with the wedge moves upward, the gate together with bush *7* mounted on it moves to the left under magazine *4* and a blank drops into nest *5* of the bush. When the wedge moves down, the gate shifts leftward and feeds the blank to the punch. The finished cap is pushed by the knock-out into bush *7* and is removed from the die when the gate moves to the left. When the gate moves to the right, magazine *4* is closed at the bottom by slide *2* which prevents the

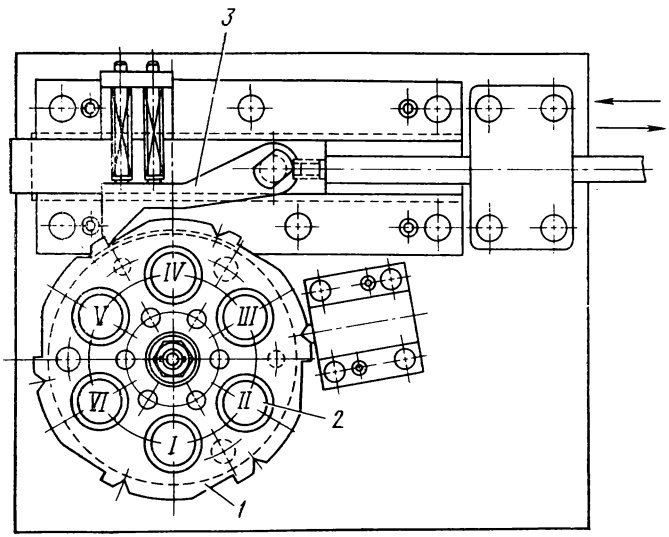


Fig. 144. Diagram of dial feed

blanks from falling out of the tool. Gate feeds may also be driven by a system of levers connected to the upper half of the tool.

In *tools with a dial feed*, there is provided horizontal disk *1* (dial) (Fig. 144) having several pockets *2*. The blanks placed in the pockets are fed to the tool area when the disk indexes. The disk is indexed by pawl *3* linked via a system of levers with a slide or crankshaft of the press. During each stroke of the press, the disk is automatically turned so that the pocket with the next blank enters the working zone of the tool. The blanks are usually fed into the disk pockets from a magazine similar to that used in gate feed tools.

Grab feeds are used mainly in multi-station presses. An example of such a feed is found in the multi-station automatic header described above (see Fig. 134). There are grab feeds for transfer of blanks and preforms between stations both in one plane and with lifting (three-dimensional feed).

In strip pressworking use is also made of *uncoilers 1* (Fig. 145) *which ensure formation of loop 2*. Such a loop facilitates supply of metal

to the tool when employing various feeds. When a strip tension reaches a certain value the loop becomes shorter and a follow-up lever cuts in the electric motor of the uncoiler. The uncoiler operates till the loop reaches the preset length after which follow-up lever *3*

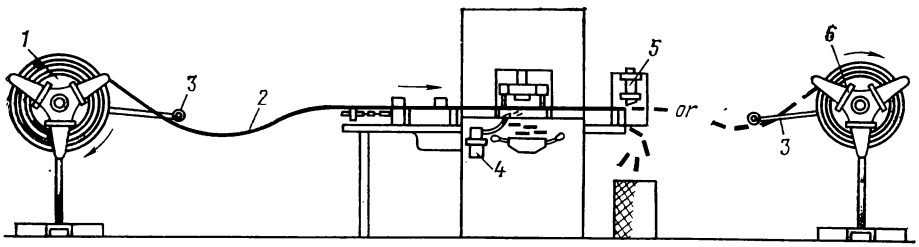


Fig. 145. Diagram of an uncoiler and scrap cutting device

cuts out the uncoiler motor. To remove finished parts, the installation shown in Fig. 145 uses pneumatic ejector *4*. Blades *5* are used to cut scrap for facilitating briquetting. If no briquetting press is available, the scrap is wound into coils *6*. The scrap recoilers are provided with an individual drive having follow-up lever *3*.

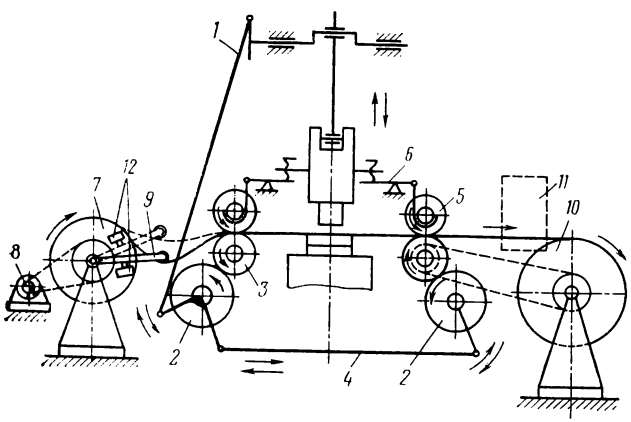


Fig. 146. Diagram of roll feed

Various roll feeds are widely used for automating supply of the material to the working zone of a tool. The *roll feeds* can be single-sided when the rolls are arranged after the tool and pull the scrap strip or before the tool and push the blank strip into the latter or, more frequently double-sided ones, i. e. both pulling and pushing (Fig. 146). In the latter case rolls *3* and *5* are arranged at both sides of the tool. They revolve in synchronism and transport the strip through the

working zone. The clearance between the rolls is adjusted by device *6*. The rolls are driven from a crankshaft by levers *1*, *4* and ratchet or friction devices *2*. When the slide moves upward the rolls turn and the strip is displaced through the feed pitch. During the slide working stroke rolls *2* are not meshed with rolls *3* and *5* so that the two latter rolls remain stationary.

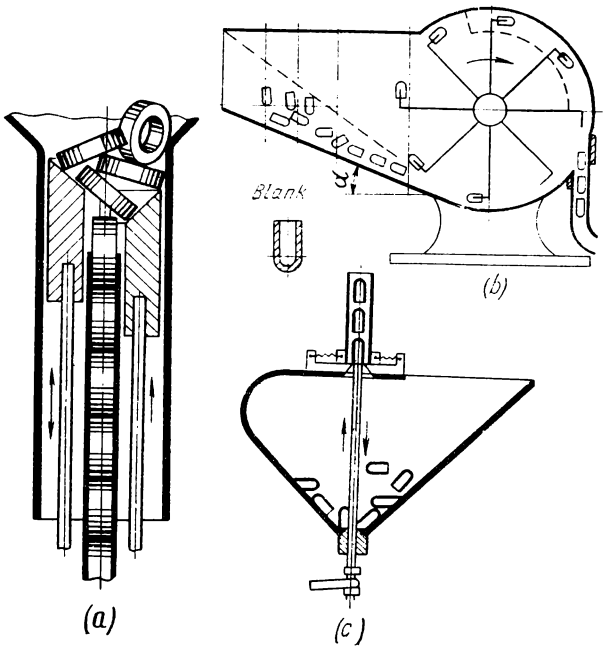


Fig. 147. Operating diagram of bunker positioning devices

(*a*) with reciprocating slides; (*b*) fitting blanks onto a rotating hook; (*c*) fitting blanks into a peg

The roll feed shown in Fig. 146 employs uncoiler *7* driven by electric motor *8*. The motor is controlled by follow-up lever *9* which breaks contacts *12*. The scrap strip is wound up recoiler *10* rotated from rolls *5* or crushed by crusher *11*.

To automate the feed of strips and sheets to the tools, use is made of strip and sheet pilers whose gripping device is provided with suction cups or electromagnets. Vertical and horizontal displacements of sheets or strips are carried out with the use of pneumatic or hydraulic devices.

To facilitate the separation of sheets and strips sticking to each other owing to the layer of grease, the pilers comprise electromagnetic peeling devices which magnetize in the same sense the ends of sheets and strips, thus making them repel each other. This ensures a reliable peeling of the top sheet or strip from the pile.

To prevent simultaneous feed of two strips or sheets, the strip and sheet pilers are equipped with control devices which automatically cut off the press if two blanks are fed at a time.

For the automatic feed of individual blanks, magazine and bunker devices of various designs are utilized.

The blanks are charged into the magazines in a definite position (see Fig. 143). In bunker charging devices special devices are used for orienting the blanks (Fig. 147) so that the latter assume a correct position in the tool feed.

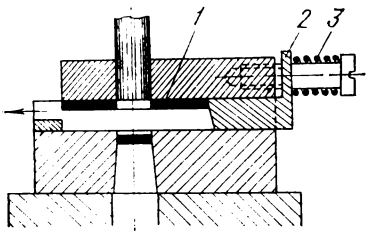


Fig. 148. Diagram of a spring-loaded knock-out for stampings and scrap

The positioning devices may include reciprocating slides (Fig. 147*a*), revolving hooks (Fig. 147*b*) onto which shell-type blanks are fitted, orienting pegs (Fig. 147*c*), vibrating devices, etc.

The finished stampings are removed by different methods. They can be removed downward through the die hole and the corresponding holes in the press bolster and bed; inserted by the knock-outs into the strip to be removed with the latter from the tool; with the aid of various ejectors, manipulators, pneumatic blowers, industrial robots, etc.

When a *spring knock-out* is used (Fig. 148), pierced part *1* is lifted by the punch, slides along the bevel of knock-out pusher *2*, moves it to the right and compresses spring *3*. When the punch lifts from the part, the latter is ejected from the tool by the pusher under the action of spring *3*.

A *hinge-lever ejector* (Fig. 149) enters the working tool area when the upper half of the tool rises. Then the pusher operates. The stamping falls onto the ejector rolls and moves along them to the container. When the slide moves down, the ejector leaves the tool area.

A *pneumatic blower* (Fig. 150) is activated by a cam mounted on a crankshaft. The blower is cut in when the stamping is pushed from the upper half of the tool.

Manipulators are articulated to the frame of a press. They are actuated by pneumatic cylinders which are engaged and disengaged by electropneumatic devices operating automatically during motion of the press slide. A vertical manipulator (Fig. 151) is provided with tongs *1* which are moved into the tool area by a lever system when the slide moves upward. The levers are moved by large pneumatic cylinder *2*. The tongs which grip the part are actuated by small pneumatic cylinder *3*. After the part is removed from the tool area the tongs are released and the part falls into a container.

Horizontal manipulators are also used.

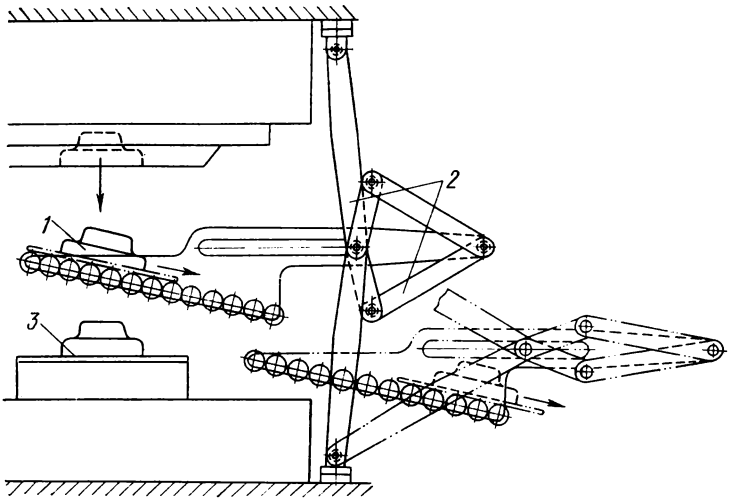


Fig. 149. Hinge-lever ejector for stampings and scrap
1—stamping; *2*—leverage; *3*—lower half of tool

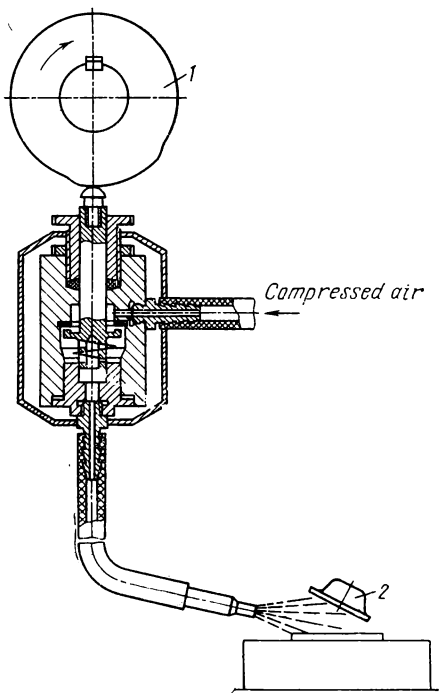


Fig. 150. Diagram of a pneumatic blower
1—cam; *2*—stamping

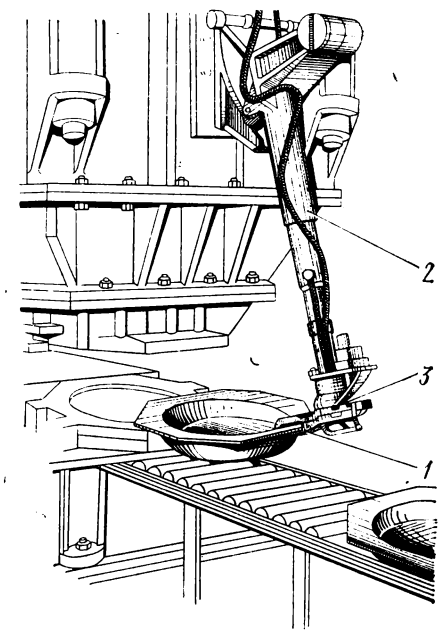


Fig. 151. Manipulator

To feed individual blanks into the tool and remove the stampings, use is also made of *industrial robots* (Fig. 152). The robots are equipped with vacuum, electromagnetic or mechanical grippers. The robot arms have several degrees of freedom. They can extend and retract, move in the vertical direction, turn relative to the vertical axis and roll over the blank by rotating about their axis.

A lot of *automatic pressworking transfer lines* are successfully operating at the USSR plants. They include multi-purpose or special equipment having devices for feeding blanks, removing workpieces and

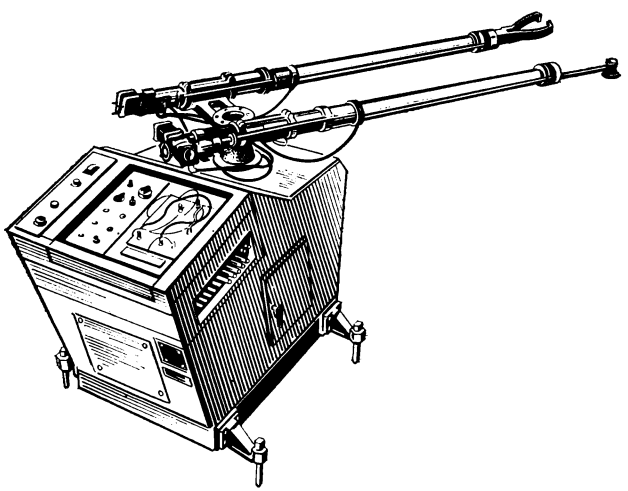


Fig. 152. Industrial robot

scrap, for inter-station transfer and rolling over of preforms and other operations. Many pressworking lines also perform such operations as welding, cleaning of parts, heat treatment, painting, etc.

The inter-station transfer of preforms in the automatic sheet stamping lines is effected with the use of step-by-step, belt and apron conveyers, stationary and vibrating chutes and troughs.

Automatic lines may be single or group ones. The former are intended for making a certain part, and the latter — for similar parts (the line is reset for each new batch).

The lines are driven by hydraulic, pneumatic and electromagnetic devices. Their mechanisms have interlock systems which stop separate presses or the entire line in the case of troubles (no blanks fed, improper transfer of blanks, etc.).

As regards their operating principle, the transfer lines can be divided into synchronous, non-synchronous and combined lines. In the synchronous lines the transfer devices are rigidly interconnected and transfer blanks, preforms and parts synchronously at a constant rate. Such lines can comprise several presses.

When there are a large number of presses, the lines are divided into separate sections operating independently but in synchronism with each other.

In non-synchronous lines the transfer devices are not interconnected directly and can be activated by the part (blank) fed from the previous station. Such lines are more versatile, they can include devices for keeping inter-operation preform stocks. The combined transfer lines include both synchronous and non-synchronous transfer devices.

The pace of a transfer line is set depending on the production programme and line capacity. Automatic lines for sheet metal stamping are employed for producing automobile parts, electrical and radio apparatus, consumer goods.

Examples of modern transfer lines are a steel bathtub stamping line, clutch case stamping line, motor brake drum flange stamping line (Fig. 153), etc. The latter comprises two presses.

In this line, the blanks are stacked on sheet piler table *13* which is raised by motor *14* as the blanks are used up. The top blank of the pile is lifted by suction cups *8* secured to movable frame *10*, displaced by pneumatic cylinder *12* with the aid of a special rack transmission.

The frame feeds the blank to the working zone of intermittent feeder *11*. In this position the blank is released from the suction cups and lowered into the nest of the feeder. The nest is moved by pneumatic cylinder *16* into the area of tool *17* of press No. 1. Spray gun *9* is engaged to coat the blank with atomized lubricant fed from tank *15*. Then the press is switched on automatically and the blank is cut out and drawn in the compound tool. The drawn preform is lifted with the upper half of the tool, where it is held by electromagnet *7*. When the slide reaches the top position, the magnet is switched off and the preform drops onto chute ejector *6* which discharges it onto inter-operation conveyer *5* driven intermittently by a separate pneumatic cylinder.

The scrap formed after blanking is cut up in the tool and drops onto chute *18* which discharges it onto belt conveyer *19*. The intermittent conveyer moves drawn preform *4* and delivers it to the working zone of tool *3* of the second press where holes are punched. The finished workpiece is removed from this press onto belt conveyer *1* in the same way as from the previous one, by means of an electromagnetic device and chute ejector *2*.

Another example of an automatic line is the line for stamping shaped disks (Fig. 154). It comprises strip feeder *1*, shears *2*, four presses *3* for blanking and forming, stamping shaving and chamfering device *4* and automatic monitoring unit *5*.

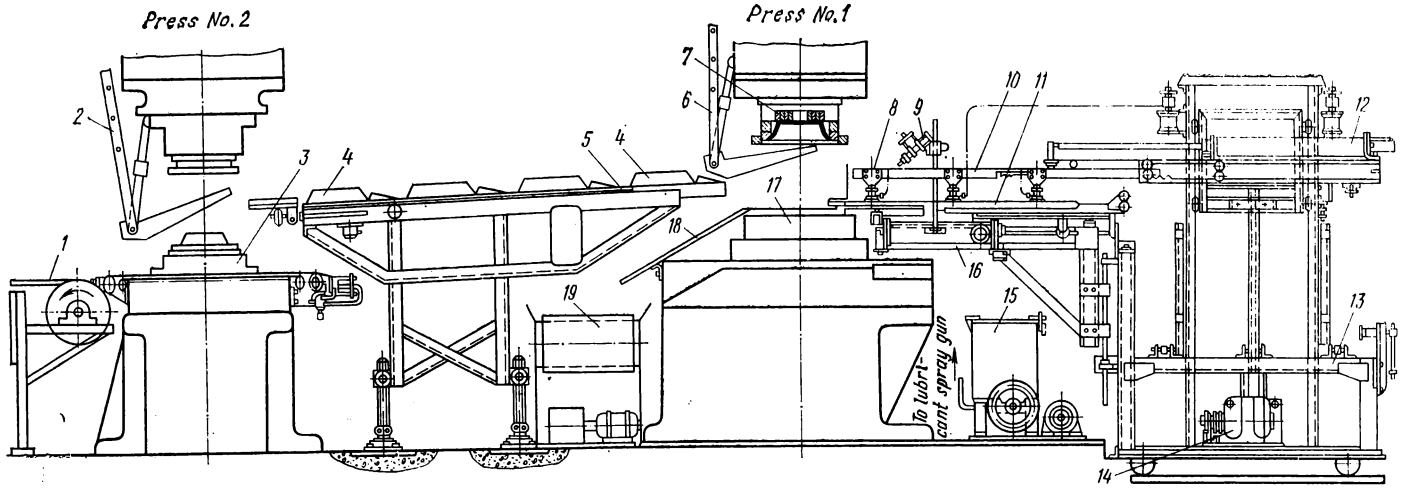


Fig. 153. Automatic transfer line for stamping drum brake flanges

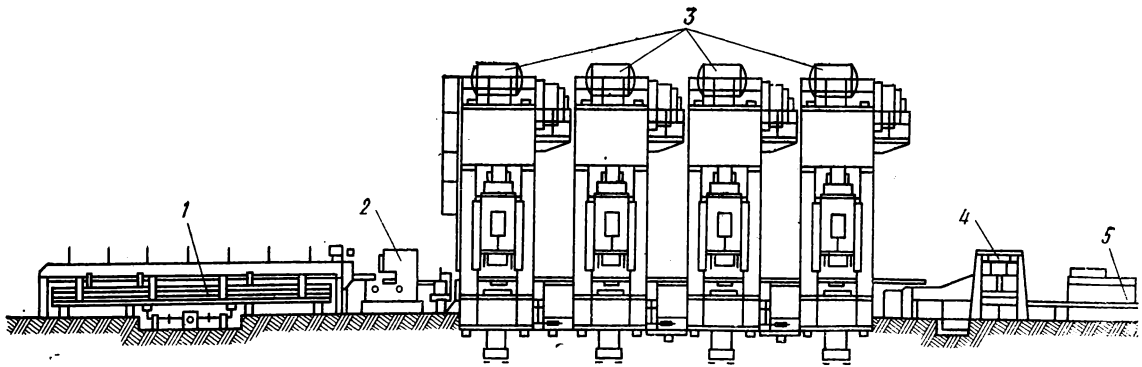


Fig. 154. Automatic transfer line for stamping shaped disks

Review Questions

1. What types of equipment are used in cold pressworking shops?
2. Describe the design of a crank press.
3. What are the double- and triple-action mechanical presses?
4. What are the design and operating principle of a hydraulic press?
5. What types of devices are used for feeding strip into the tool area?
6. Describe the design of a cold pressworking transfer line.

Chapter X

ELECTRICAL EQUIPMENT OF PRESSWORKING MACHINES

1. Electric Drive

An electric drive is an electromechanical device intended to actuate the working members of various mechanisms and machines. The electric drive consists of an electric motor, control and protective devices and a mechanical transmission. The mechanical transmission may include a clutch, reduction gear, speed-change box, etc.

The electric drive has undergone considerable changes with progress of technology. Initially a drive common to the whole plant was used. An electric motor was installed in the plant building and tourque was distributed by means of mechanical transmissions. Interstorey mechanical transmissions presented a severe problem to eliminate which a group electric drive was developed.

Separate high-power electric motors drove a large group of machines, while each machine of the group was driven via an individual transmission. Such a drive was uneconomical owing to great losses in the transmissions and was replaced with individual electric motors. The use of an individual electric drive for each machine has improved the labour conditions, facilitated laying out of shops, simplified operation of handling equipment.

Further development of technology has resulted in the creation of a new type of electric drive, i.e. a multi-motor drive. In a machine with a multi-motor drive each working mechanism is actuated by a separate individual motor. Such an electric drive is well adapted for automation and slaving of separate motions.

To control a machine, the operator uses push-buttons, pedals, switches, speed controls. The designers try to automate control of the electric drive to the maximum possible degree since rapid change

of monotonous motions involved in manual control fatigues the operator and decreases the rate of work.

Automation increases productivity and improves labour conditions. The worker is freed of monotonous toil to become an operator of a highly efficient equipment. With automatic control, the operator has only to supply the first pulse (push the button) to engage the required mode of the drive and then check accomplishment of the mode.

Electric drives are usually energized from three-phase 380-V, 50-Hz mains. Powerful motors are fed from 500-V mains.

2. Electric Motors

The pressworking machine drives usually employ high-slip squirrel-cage induction motors of up to 100 kW in power. If higher power is required, use is made of the similar motors with end rings and slip controller, i.e. a resistor in the rotor winding. Synchronous and dc motors are also installed on some machines.

The operating principle of an induction motor is based on the utilization of a revolving magnetic field. An elementary example of such a field can be obtained by rotating a horseshoe magnet about a magnetic compass needle. The magnetic needle will rotate in the same direction and with the same speed as the magnet. If a closed conductor on a pivot is disposed in the revolving magnetic field instead of the needle, the electromotive force (emf) will be induced in the conductor by the magnetic field crossing it in rotation.

Electric current appears in the closed conductor (loop) under the action of the emf. The interaction between the revolving magnetic flux and current in the loop creates a force which tends to turn the conductor in the direction of the field rotation. The loop starts rotating unidirectionally with the field. However, the loop speed of rotation n is always lower than the speed of rotation n_0 of the field, i.e. asynchronous (should they be equal the conductor loop would never be intersected by the magnetic field, no emf would be generated, no current would be induced in the conductor, and hence no interacting force would result). The motors based on this principle are termed asynchronous or induction motors. The value characterizing the delay of the loop speed from the field speed is called slip (S)

$$S = \frac{n_0 - n}{n_0}$$

Usually the value of slip S changes from 0.03 to 0.15.

In an induction motor, the revolving magnetic field is created by three-phase alternating current flowing along fixed stator windings rather than by a mechanical rotation of the magnet.

The main components of three-phase induction motors are a stator (fixed part) and a rotor (revolving part). If an iron cylindrical rotor is placed inside a revolving magnetic field of a stator, currents will be induced in the rotor body, they will interact with the revolving magnetic field and cause rotation of the rotor. The speed of this rotation will be lower than the speed of rotation of the field.

To increase torque and decrease heating losses, the rotor is made not as a solid cylinder but of separate steel disks 0.3 to 0.5 mm thick, insulated from each other. Copper or aluminium bars are lodged in the slots of the disks and are brazed to rings at both ends. Such a rotor and its winding are called "squirrel-cage" ones.

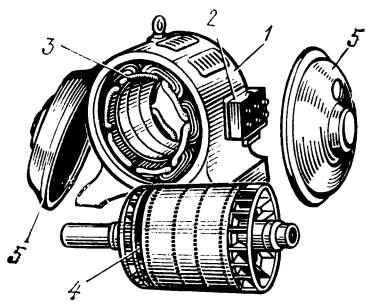


Fig. 155. Main components of a three-phase asynchronous motor
1—frame; *2*—terminal box; *3*—stator pack with a winding; *4*—rotor with an impeller; *5*—end shields

The stator (Fig. 155) of an induction motor comprises a frame into which stator pack *3* is forced and terminal box *2*. Frame *1* is made from iron, steel or aluminium alloys. The stator pack is assembled from thin stamped laminations of electrical steel. Slots are notched in the laminations for lodging the winding. Bearings are forced in the end shields.

The terminal box is intended to secure the stator winding leads and connect power wires.

An *induction squirrel-cage motor* is simple in design and reliable in operation. However, the starting current of such motors exceeds the rated one by 5 to 8 times which may cause voltage drop in the power supply mains.

The induction motor torque is proportional to the square of the mains voltage at a given speed of rotation. Therefore, when starting a high-power induction motor, the other motors operating with an overload can stop. To avoid this, an induction motor without a starting current limiter may be started only if its rated power does not exceed 25 per cent of the power of the shop mains transformers.

The starting current may be decreased up to 1.5-2.5 of the rated one when using phase-wound motor with a rheostat connected to the rotor circuit.

In contrast to the squirrel-cage induction motor, the phase-wound motor has identical windings on the rotor and stator. The leads of these windings are star connected and joined with the slip rings. The brushes contacting the slip rings are connected to starting rheostats. This motor is used to ensure smooth starting, limit the starting

current, obtain high initial starting torque and adjustable speed of rotation.

The ac commutator induction motors have rotors (called armatures in these machines) the windings of which are connected to the commutator. The motor armature rotates with a speed other than that of the generator, i.e. the motor is asynchronous. The commutator and brush assembly serves to convert a current of one frequency (commutator-connected winding) to a current of another frequency (brush-connected circuit). The commutator provides for smoothly controlling the speed of rotation within a wide range without decrease of power.

The commutator machines can be operated both in the motor and generator modes. However, they are intricate in design and several times as expensive as the induction motors.

Synchronous motors comprise a stator similar to that of the induction motor and a rotor being essentially a shaft carrying a permanent magnet and rotating in bearings. Permanent magnet is often replaced with an electromagnet. The rotor is stacked from electrical steel laminations shaped to form pairs of salient poles. The number of pole pairs determines the speed of rotation of the motor shaft. One pair of poles gives 3 000 rpm, two pairs—1 500 rpm and so on. A low-speed motor can be obtained by providing a sufficient number of pole pairs. Each pole carries a winding. The windings of the pole pairs are connected in series while their leads terminate in two slip rings on which the brushes ride. The brushes are connected to a dc source.

When the stator winding is connected to a three-phase ac mains, a revolving magnetic field is generated. It interacts with the field of the permanent magnet and creates an interacting force unidirectional with the field rotation. This force makes the rotor turn at the speed of rotation of the field. The rotor speed does not change when the antitorque moment increases to the critical one.

Synchronous machines are reversible, i.e. they can operate both in the motor and in the generator modes (only synchronous generators are used at power plants).

Star and delta connection of stator windings. If three finish leads of the stator winding are connected at one common tap 0 (zero point), such a connection is termed "star" (Fig. 156*a*). The line wires are connected to starting leads B_1, B_2, B_3 of the same windings, while the motor zero tap 0 is connected to the zero tap of the generator. The wire connecting the motor zero tap with that of the generator or transformer is called the *neutral wire.*

Such a four-wire three-phase current system has two different voltages. The voltage between the line and neutral wires or between the starting and finish leads of any stator winding is called a *phase voltage.* The voltage between two line wires is called a *line voltage.* The line voltage is $\sqrt{3}$ times as great as the phase voltage.

In a delta connection of the stator windings finish lead E_1 of the first winding (Fig. 156*b*) is connected to starting lead B_2 of the second winding, finish lead E_2 of the second winding is connected to starting lead B_3 of the third winding and the finish lead E_3 of the third winding is connected to starting lead B_1 of the first winding. Such a connection gives only one line voltage equal between any two line wires.

Depending on the shop mains voltage, the motor windings are either star or delta connected. For instance, if the mains voltage is 380 V, the star connection is used, if it is 220 V, the delta connection.

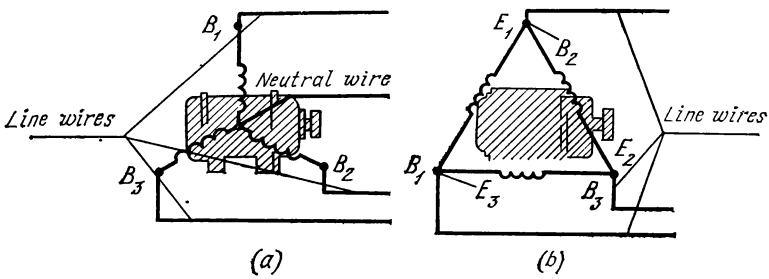


Fig. 156. Winding connection of a generator or an electric motor (*a*) star; (*b*) delta

DC motors. A dc **motor** has a frame in the form of a continuous mild steel ring. The frame carries main poles *N* and *S*. Disposed on the shaft between the poles is a cylindrical armature consisting of electrical steel laminations. The armature has slots for lodging insulated-wire windings. The armature winding comprises several coils. The coil leads are connected to the commutator bars. Each coil is connected to the diametrically opposite poles. Stationary brushes ride on the commutator.

The commutator consists of wedge-shaped copper segments arranged around a steel hub to form a cylinder and insulated from the hub and from one another.

A field winding is arranged on the main poles of the motor.

When connected to a dc source, it creates the main magnetic flux of the machine.

If the brushes are connected to a dc mains, a current will flow through the armature winding. Interaction of the current in the armature winding with the magnetic field created by the field winding forms an interacting force, and hence, the torque. The armature starts rotating. The commutator ensures that the current flowing along the armature winding turns arranged under the main poles remains constant.

The direction of rotation of the armature can be reversed by changing the polarity of voltage applied to the field winding or to the armature.

The advantage of the dc motor is the possibility to control its speed of rotation within wide limits.

High-torque electric motors are widely used in modern variable-speed drives. These motors are distinguished for the use of powerful permanent magnets instead of field windings. Such motors provided with special semiconductor rectifiers (thyristor converters) are employed in variable-speed drives with a speed adjustment ratio of up to 1 : 1 000 000.

The dc machines are reversible, i.e. operable both in the motor and in the generator modes.

Squirrel-cage induction motors are widely used in pressworking equipment. These are relatively cheap, reliable and economical machines. The speed of rotation of such motors is almost independent of load variation.

On heavy presses when a power of above 200 kW is required, synchronous motors are installed. Such motors ensure a constant speed of rotation and are more economical than the induction ones at high loads.

Some pressworking machines require decrease of the rotor speed at an increase of load. This requirement can be met by high-slip induction motors and end-ring induction motors with a rheostat connected to the rotor circuit.

When a wide-range variation of the rotor speed is needed, the variable-speed dc drives are used.

3. Control and Protective Devices

The control and protective devices are intended to start, reverse, brake and adjust the speed of electric motors. The control devices are divided into two main groups: manual (non-automatic) control and automatic control devices. The protective devices, as their name implies, serve to protect the electric motor against faults.

The main contacts of the modern starting control devices are of the knife or push type and are made from copper. The copper contacts are sometimes silver plated to decrease cross-path resistance which decreases heating and extends the life of the contacts.

Manual control devices. A knife switch is the simplest device for the manual control of pressworking equipment. It is used as a master switch intended to de-energize the machine during dead periods.

There are single-, double- and three-pole *knife switches* (Fig. 157*a*, *b*, *c*). They may have one, two or three hinged pole knives. The knives are interconnected by a cross bar made from an insulation material. To cut in the switch, the knives are turned in their hinged joints by

the handle and plugged into the poles. To cut out the switch, the knives are withdrawn from the poles.

The knife switches with central and side-mounted handles are frequently used. In addition to the main contacts, the knife switches

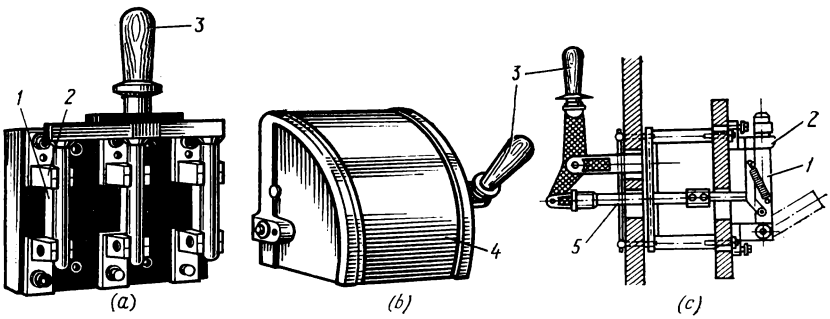


Fig. 157. Three-pole knife switch
(*a*) open design; (*b*) enclosed design; (*c*) controlled by a mechanical drive; *1*—knife; *2*—poles; *3*—handle; *4*—enclosure; *5*—rod

may include interlock contacts designed for controlling low-current circuits which are used for cutting in various indicator lamps.

The pressworking equipment control devices include also rotary switches which are very compact as compared with the knife switches. The rotary switches are used for manual control of dc and ac circuits.

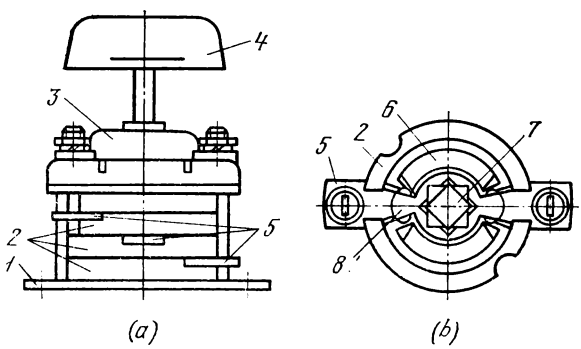


Fig. 158. Rotary switch
(*a*) general view; (*b*) section (packet); *1*—yoke; *2*—insulator; *3*—cover; *4*—knob; *5*—fixed contacts; *6*—spark-arresting fibre washer; *7*—square axle; *8*—spring movable contact

A *rotary switch* (Fig. 158*a*, *b*) has spring contacts *8* capable of rapidly breaking and making the circuit. When knob *4* is turned, first the spring is tensioned and then square axle *7* is forced by the spring to turn quickly and open or close contacts *5* and *8*. Owing to such a high speed of action, the electric arc resulting from breaking of the circuit is positively extinguished.

Button systems are most widely used for controlling the electrical equipment of pressworking machines. Switching on is effected in such a system by a special device termed "contactor" which makes the power circuit when the start button is depressed. The buttons are returned to the initial position by springs.

The START button is sunk for 5-7 mm to prevent inadvertent switchings. The STOP button is painted red.

To ensure safety (preclude getting of operator's hands into the working zone) some machines are equipped with two-button switching. The buttons are so spaced that it is impossible to push them by one hand and the press is cut in only when the two buttons are depressed simultaneously.

The button control is frequently duplicated by a pedal control circuit. When the foot presses against the fluted surface of the pedal, the latter moves the button switch pusher and closes the control circuit. The spring returns the pedal to the initial position. To preclude inadvertent switching, the pedal is covered on top with a rigid guard. The pedal starting devices can be connected to a machine through a flexible hose with wires, which permits the pedal to be placed where it is convenient for the operator.

Controllers serve to change over ac and dc systems and hook up various braking and reversing circuits. There are drum, cam and flat controllers. The drum controllers are used for the motors up to 75 kW in power with the number of switchings not exceeding 240 per hour.

The cam controllers are employed for high-power motors with the number of switchings of up to 600 per hour. The flat controllers have found application for remote control from a console or control board.

Toggle switches are used for operating on-line control, signalling and local illumination circuits.

Remote control devices. The remote control devices include control buttons, master controllers, limit switches, contactors, magnetic starters, automatic switches, and relays.

This equipment is designed for remote and automatic control of both separate mechanisms and whole production complexes.

Contactors are the solenoid-operated switches used in dc and ac remote or automatic control circuits. AC contactors are rated for 220/380 V and 10 to 600 A.

Magnetic starters are three-phase ac contactors with make main contacts. They may include thermal relays. The magnetic starters are controlled remotely with the aid of the START/STOP buttons.

The diagram of remote control of a non-reversing squirrel-cage induction motor is shown in Fig. 159. Three-phase voltage is fed to the stator of electric motor M from a three-pole knife switch S. The switch provides for cutting out the motor for repair or in the case of failure of the magnetic starter. Next, the power circuit includes fuses $1F$, $2F$, $3F$ which are usually arranged on a group distribution

board. The fuses protect the circuit against shorts. The main contacts of the contactor C connect or disconnect the motor stator winding.

The main movable contacts are always connected to the motor, while the constantly energized stationary contacts are connected to the mains. Such a connection increases safety in maintenance. Thermal relays $1TR$ and $2TR$ are connected to two phases since overcurrent

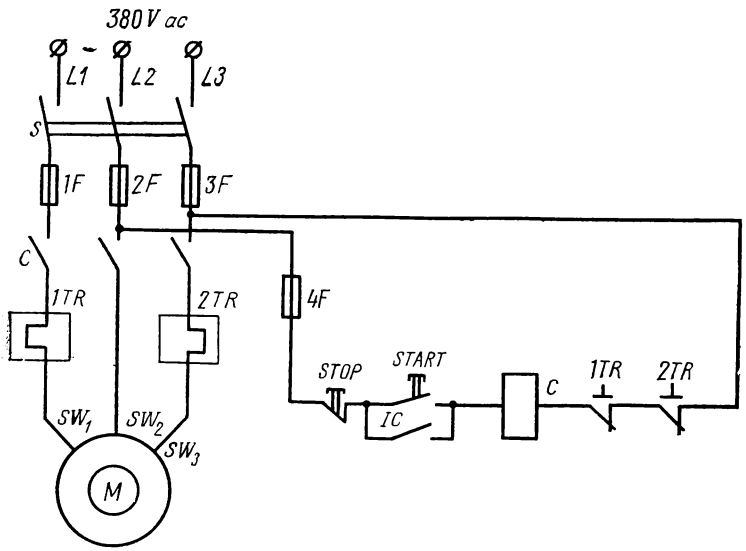


Fig. 159. Schematic diagram of a non-reversible induction motor remote control

can be encountered at least in two wires. These relays protect the motor from prolonged overloads and two-phase operation.

The control circuit is fed through a knife switch and fuses of the main circuit. Besides, the control circuits are protected with individual fuse $4F$. As seen from the diagram, the control circuit and the power circuit are energized with the same voltage.

The STOP and START buttons are cut in the control circuit. The STOP button has a break contact, while the START button, the make one. To start the motor, the knife switch is cut in and the START button is depressed. The circuit of the contactor C coil closes and a current is fed through fuse $4F$, buttons STOP and START, contacts of thermal relays $1TR$ and $2TR$. The current flowing along the contactor coil magnetizes its core, the armature moves in and makes the main contacts. The leads of stator windings SW_1, SW_2, SW_3 are connected to the power circuit leads L_1, L_2, L_3 and the motor starts.

The interlock contact of the contactor *C* gets closed simultaneously with the main contacts and the START button can be released. It returns to the initial position by the spring.

To cut out the engine, the STOP button is pushed. Now the supply circuit of the contactor coil is broken, the main contacts open by gravity or under the action of springs and the stator winding gets disconnected from the mains.

This circuit effects zero phase-sequence protection of the motor. If the mains voltage drops down drastically or disappears, the contactor is cut out and disconnects the motor from the mains. The interlock contact *IC* opens so that when the voltage is re-applied, no start of the motor will occur.

In the case of prolonged overload, thermal *relays* operate to cut out the contactor and the motor. The contacts of relays *1TR* and *2TR* will return to the initial position only after the bimetallic strips cool down.

The pilot relays are designed to switch commands and interlock the control circuits. These are solenoid-operated switching (distributing) devices operating on the principle of a contactor. The structural difference is that instead of power (main) contacts, the pilot relays have a group of make, brake and change-over low-current contacts. The relays and contactors are marked by the same schematic symbols.

Change-over switches are designed for cutting in and out the control circuits and are essentially manual switching devices. The control change-over switches may have a number of fixed positions and a corresponding number of contacts made or broken in the respective position. Change-over switches come in a wide variety of designs differing in positions of knobs and number of contacts.

Limit switches are push-type switching devices. They are intended to stop the working members of the press in the designed positions.

A limit switch comprises a body, a rod (lever) and make or break contacts linked with the latter. When, say, a press slide reaches the desired position, the cam mounted on it pushes the rod of the limit switch, the contacts of the switch operate to supply signals to the control circuits for cutting in or out the drive. The manufacturer can deliver pilot relays and limit switches with a contact combinations ordered by the customer.

Protective devices. Abnormal or emergency conditions that can be encountered in operation of the press electric drive include short circuits, overcurrent (an abnormal current greater than the full load value), open phase, short-time drop or disappearance of supply voltage.

The electric installation safety rules stipulate that each drive should be protected from all abnormal conditions mentioned above.

The protective devices include fuses, thermal relays, automatic switches and overcurrent relays.

Disconnection of a mechanism protected with *fuses* is effected owing to melting of a special link made from calibrated wire or strip.

Screw-plug and tubular fuses are widely used in pressworking equipment. The screw-plug fuses are designed to protect control and power circuits and pass currents up to 60 A. The tubular fuses pass currents up to 350 A and protect medium- and high-power electric motors. Fuse protection of electric motor and power line is far from perfection since the current value at which the fuse link is melted depends on cooling conditions and overcurrent duration.

The *automatic air-break switch* is the most sophisticated device which allows infrequent manual switching on and off of power circuits and automatic breaking of the latter in the case of shorts or overloads. The protective functions are performed by tripping devices. The automatic switches may include electromagnetic, thermal, voltage or any combination of trips.

An *electromagnetic trip* is a sort of an overcurrent relay and serves to protect the circuits from shorts. A *thermal trip* is a thermal relay adapted to protect the circuits from overloads. A *voltage trip* is a variant of a conventional voltage relay the armature of which is connected to the main contacts of the automatic switch, while the coil is arranged under the main contacts. When the automatic switch is cut in manually and voltage exists in the mains, the relay picks up and keeps the contacts closed. If the mains voltage disappears or drops down, the coil is de-energized and the armature returns to the initial position, thus breaking the automatic switch contacts.

The electrical equipment is arranged in control cabinets. The beds of pressworking machines experience considerable jarring which can cause malfunctions of the electrical devices. Therefore, the control cabinets are arranged separately but not far from the machine. The cabinets are of standard designs. If the electrical equipment comprises a number of identical units, they are pre-assembled as separate panels of electrical components. The cabinets accommodate all the protective and automatic control devices, amplification and drive control circuits, magnetic amplifiers, power sources, etc.

4. Electrical Measuring Instruments

Most of the instruments used for measuring electrical quantities are of the electromechanical type (moving-coil, moving-iron, electrodynamic instruments, etc.).

The moving-coil instruments operate on the principle of interaction between the permanent magnet field and a conductor through which a current is passed. The restoring torque is created by springs. When current flows through the coil, the latter deflects through an angle proportional to the current value.

The construction of a moving-iron instrument is illustrated in Fig. 160. Iron vane B is arranged near coil A. When the current is passed through the coil, the vane is pulled into the coil, thereby turning pointer C. Cylinder D in which piston E is moving damps oscillations. The spring coupled with the pivot of vane B creates a restoring torque.

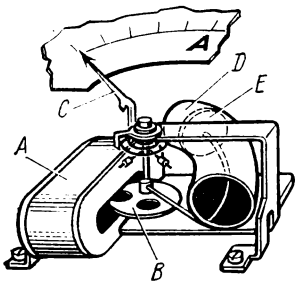


Fig. 160. Construction of moving-iron instrument

The voltmeters and ammeters can be based both on the moving-coil and moving-iron system.

A *voltmeter* (Fig. 161*a*, *b*) is always parallel connected to the circuit being measured; an ammeter (Fig. 162*a*, *b*) is connected in series. To measure high currents and voltages the moving-coil ammeters and voltmeters are connected via series resistors or shunts (Fig. 162). The ammeters and voltmeters based on other systems are connected through instrument current and voltage transformers.

A *wattmeter* is used for measuring the active power in an electric circuit. The active power is a power in a resistive circuit. It character-

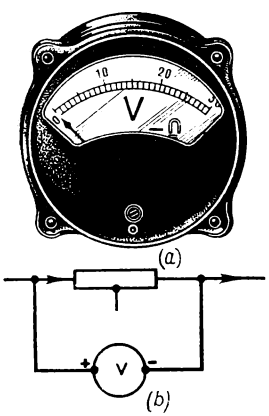


Fig. 161. Voltmeter (*a*) and its connection to circuit (*b*)

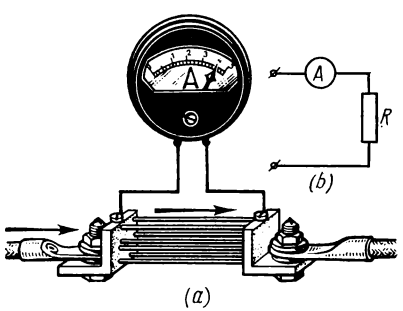


Fig. 162. Ammeter with a shunt (*a*) for measuring high currents and its connection to circuit (*b*)

izes the magnitude of energy irreversibly converted into other types of energy for 1 s.

To measure electric energy consumption, watt-hour and var-hour meters are installed at the factory or shop substation. The meter readings are used for paying electricity bills. Depending on their

design, the meters are connected to the mains either directly or through a transformer.

Frequency meters are instruments for measuring the frequency of an alternating current in the power supply circuits. These are connected directly to the circuit up to a voltage of 380 V or through a voltage transformer in the case of higher voltages.

5. Working Station Power Supply. Wiring

Large electric power stations are connected by transmission lines with substations which feed industrial enterprises. A voltage of 10 kV is supplied from a power grid substation to an industrial substation where the voltage is stepped down to 380 V. This voltage is passed via aerial or underground power lines and indoor wiring directly to the loads (electric motors, illumination lamps, etc.).

Industrial power supply is usually effected via the networks of two types, namely, radial and trunk networks. With a radial network, the main loads are fed through independent lines, while if a trunk network is used, the loads are connected to a trunk, i.e. a common distributing line. The trunk network supply is more reliable, and less expensive.

Shop low-voltage circuits are usually 380/220 V (220/127 V at older enterprises) four-wire (three phases and a neutral wire) systems. The illumination lamps are connected between a phase wire and a neutral one to obtain 127 or 220 V; electric motors and other loads are connected for 220 or 380 V supply.

Standard fixtures are used for illuminating shops. Local luminaires are intended to intensify illumination of the working station and are only an addition to the overhead lighting.

Local luminaires may be stationary or portable. Commercial stationary luminaires include a step-down transformer (127, 220, 380, 500/12-36 V, 50 W), a fuse and a switch. It may further include a 6-V outlet for signalling circuits.

To supply voltage to the working station from the factory or shop substation, buses and cables are used. A bus is an aluminium strip secured on insulators at a height precluding mechanical damage or inadvertent contacting.

Cable lines are run in pipes, cable ducts in the floor and in troughs. Copper and aluminium cables with rubber or other insulation are used for the purpose.

Wiring. Power from the transformer substation is supplied via buses and cables to a distribution board located near the transformer. From the distribution board power is transmitted through knife switches, fuses or circuit breakers over cables and trunk wires to the power and lighting distribution points and boards in the shops, and then via cables and wires to the loads.

Stationary leads to the machines are usually made of cable run in pipes under the floor. The cable portion between the pipe outlet and terminal box is protected with a flexible metal hose.

Movable leads to the moving parts of a machine or mechanism are made of stranded copper wire with rubber insulation enclosed in armored flexible sealed metal hose or rubberized-fabric hose.

Wiring may be of the indoor and outdoor type. The indoor wiring is laid inside a building with the use of insulated wires, buses or cables. It may be open (along the walls, ceilings, trusses) or flush (under the plaster, in the floor or ceiling).

The outdoor wiring is run open along the external walls of buildings and structures, between them, under sheds or in underground cable ducts.

To tap the line, use is made of junction boxes from where leads are run to the machines. Terminal strips are widely employed for tapping and switching in electrical cabinets. A terminal strip is a plastic slab with terminals for connecting wiring.

All metal components of electrical apparatuses which do not carry current (casings, enclosures, cabinets, pipes, etc.) should be reliably earthed. The pressworking machines should be earthed with special care to withstand constant impacts and shakes.

Review Questions

1. What does an electric drive consist of?
2. Describe the main components of an induction motor.
3. Outline the remote control equipment.
4. How are a voltmeter and ammeter connected to the circuit?

Chapter XI

ADJUSTMENT AND REPAIR OF PRESS TOOLS

1. Mounting and Adjustment

After a tool is made and thoroughly checked for compliance to the drawing and specifications, it is tested on a press by making a few parts. The latter are checked for correct shape, dimensions and surface finish. If any faults in the manufacture, assembly or design of the tool are traced, they are eliminated, and the tool is handed over to the shop which has ordered it.

Mounting a tool is a very important and labour-consuming operation. It should be performed by skilled workers (setters-up or adjust-

ers). The sequence of steps for mounting and adjusting tools is indicated in the relevant instructions and adjustment charts.

A reliable operation of a tool depends greatly on the condition of the press where the tool is to be mounted. Therefore, the presses should be periodically checked for accuracy. Deviations from the specified accuracy lead to premature wear of press tools or breakdowns.

Tools shall be mounted only on the presses specified in the chart. All foreign objects should be removed from the tool space and the surfaces of the press punch holder and die shoe should be wiped clean.

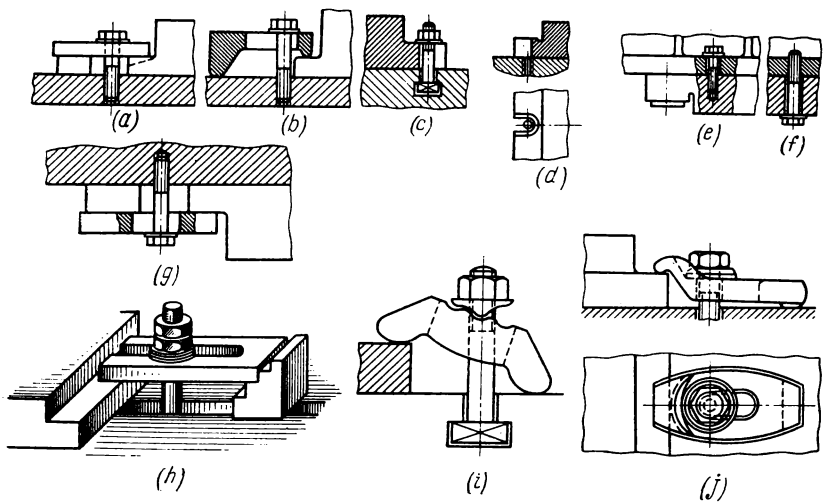


Fig. 163. Method of securing tools to presses
(*a*) with strap; (*b*) with cramp; (*c*, *d*) with bolts in slots; (*e*, *f*) with bolts through holes in the press slide or in the punch holder; (*g*) with a strap or cramp by the flange of the punch holder; (*h*, *j*, *i*) with clamps

This done, the slide stroke and shutheight should be adjusted.

When mounting small and medium-size tools with guides on crank presses, proceed as follows:

Measure the height of the closed tool and see whether the shutheight of the press is sufficient. A tool can be mounted only on a press in which the distance between the slide in the bottom position and the bed plate exceeds the height of the closed tool.

Next, move the press slide with the use of its motor or manually to the bottom position, undo the nuts of the insert (quill) attachment studs and remove the insert from the slide. Position the tool on the bed and bring the tool shank into the hole in the press slide. Reinstall the quill and tighten its attachment nuts. Then slowly move

the slide up and down to check proper mounting and eliminate misalignment if any. Secure the die shoe on the bed by using straps, cramps, bolts, clamps (Fig. 163*a* to *j*). When using clamps (dogs), see to it that they are parallel to the bed and rest on the shoe and a

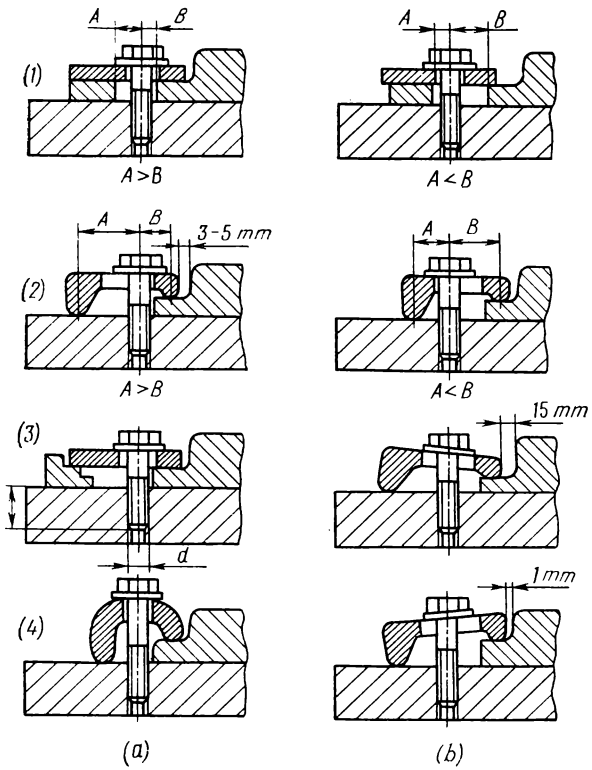


Fig. 164. Methods of securing tool to the bolster plate
(*a*) correct; (*b*) wrong

spacer simultaneously. Never replace spacers (Fig. 163*h*) with sets of straps, nuts, etc., otherwise the attachment may get loose and breakage of the tool and press may result.

Examples of correct and wrong attachment of tools to the die shoe are shown in Fig. 164*a*, *b*. Unreliable attachment (Fig. 164*b*) may stem from excessive distance between the attachment bolts and the die shoe (*1* and *2*), misalignment of the support cramp (*3* and *4*), excessive (*1* and *3*) or insufficient (*4*) distance between the strap or cramp and the die shoe wall.

Tool mounting should be convenient and reliable, i.e. ensure constant position of the tool in the course of operation.

When the slide is lifted, the tool guide posts should not move out of the bushes.

After the punch holder and die shoe are fastened, perform check stamping finally adjusting the slide position with the aid of an adjustment screw. To increase the distance between the slide and the bed, turn the pitman screw counterclockwise, to decrease said distance, clockwise.

After finally adjusting the slide stroke, check tool by performing idle strokes and check stamping. If no malfunctions are detected, secure the set bolts of the slide adjustment screw and lubricate the guide posts of the tool. Tighten the bolts gradually, alternately and evenly.

When mounting a tool with mechanical knock-outs, the latter require additional adjustment. In so doing check the damping pin length and make sure the holes in the press die shoe are not clogged with scrap.

There are particular requirements for adjusting tools of different applications. For instance, punches of an open or closed blanking tool should lower into the die hole through at least 0.7 of the material thickness. A bending tool is mounted closed. A specimen having the thickness by 10-15 per cent greater than that of the metal to be worked is placed between the punch and the die. When adjusting a bending tool, the setter-up turns the crankshaft manually to make sure that the slide is not wedged in the bottom position.

Small drawing tools are first fastened to the die shoe in the position corresponding to the working stroke bottom centre. Then the punch with a specimen having the thickness by 20-40 per cent greater than that of the material to be drawn (except for ironing) is lowered into the die hole. The press stroke is so adjusted as to exceed the height of the workpiece by 2.5-3 times.

The spring-loaded and rubber blankholders are adjusted so that the hold-down force is minimum at the initial moment of deforming since it increases during drawing. Some types of modern presses have pneumatic cushions which ensure a constant hold-down force throughout drawing, thus considerably improving the conditions of deforming.

When setting up sizing tools which require a thorough adjustment of the shutheight, wedging of the tool should be eliminated. Improperly adjusted shutheight may lead to breakage of the press or tool.

To remove the tool from the press, lower the slide so that the upper and lower tools close. Loosen the shank or punch holder attachment nuts and lift the slide. Undo the die shoe attachment bolts and remove the tool from the bed of the press using a crane, telpher or lifting truck.

Reliable mounting and correct adjustment of a tool ensure high quality of stampings and are indispensable for safe operation of the press. If any malfunctions or mounting defects are traced, the setter-up should immediately stop the press.

Large tool mounting is more complicated. Adjustment of such tools (especially drawing ones) requires much time. To install large

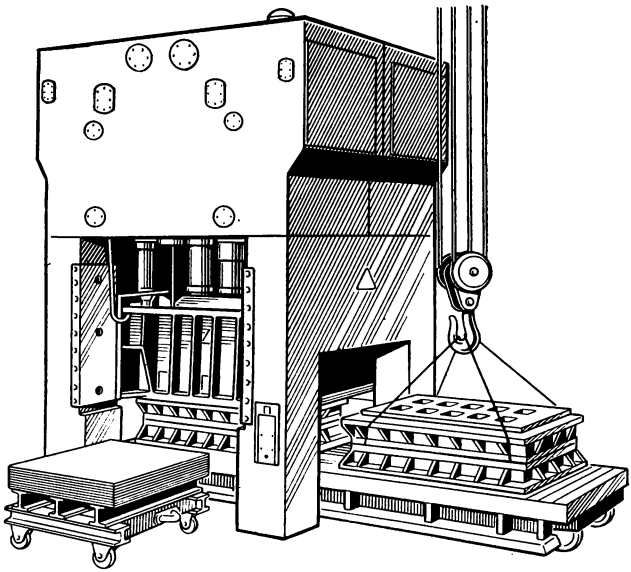


Fig. 165. Positioning of a heavy tool on the sliding bolster plate

tools on the press bed, use is made of travelling cranes, lift roller tables, electric loaders, etc. The tool lifted by a crane is placed on a support or on the bed with one end and on a support with the other. Next, the tool is moved to the working position on the press bed using various mechanisms. To simplify and accelerate mounting of large tools, new presses are equipped with extensible beds. The bed is lifted by hydraulic devices and is moved along a track to the desired position. There are presses with backward extension (towards the operator), sidewise extension of beds and with beds slidable to one side and adapted for additional perpendicular movement.

The tool is installed on the sliding bed (Fig. 165) in the course of operation of the press with the previously mounted tool.

After setting a large tool to the required position on the press bed, the slide is lowered and the upper tool is fastened to the latter. Next, the lower tool is secured to the bed. It is good policy to secure the upper tool to the slide directly by bolts which improves the re-

liability of the attachment. The attachment holes are made in the tool in compliance with the arrangement of bolts of the press slide on which the tool is to be mounted.

Modern presses are equipped with quick-release gripping devices (Fig. 166) intended to secure the upper tool to the slide. Grips *3* in the form of a bolt are actuated by hydraulic cylinders *1* which are disposed on slide *2*. Grip *3* linked with lever *5* is entered into the groove of tool *4*. Hydraulic cylinder *1* is engaged by pushing a button and the cylinder rod linked with lever *5* secures the upper tool with the required force.

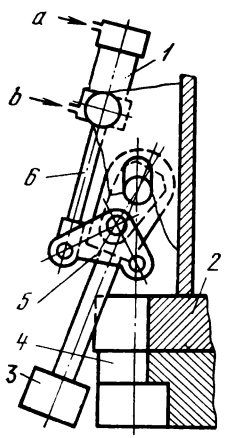


Fig. 166. Diagram of a clamping device
1—hydraulic cylinder; *2*—ram; *3*—grip; *4*—tool; *5*—lever; *6*—cylinder rod; (*a*) oil pressure for releasing; (*b*) oil pressure for clamping

Large drawing tools, such as used for drawing automobile facing parts, are very difficult to set up. First the contact surfaces of the dies and blankholders are fitted and then the forming surfaces of the dies and punches. The check stampings are thoroughly examined and all the defects are eliminated. The working surfaces are fitted by the paint-pattern method (the traces of prussian blue or black in machine oil left on the die outline the spots to be dressed). Pneumatic grinders with a set of grinding wheels are used for fitting.

2. Troubles and Remedies

Improper mounting and set-up of tools, design errors, wear of punches and dies may be a reason for rejects. Investigation in the nature of defects in stampings provides for detecting the cause of tool malfunctions and shows the way to eliminate them.

Blanking tools sometimes produce blanks with flash. This may stem from a wrong gap, displacement of the punch relative to the die, blunting of the cutting edges of the punch and die, inaccurate guidance of the upper tool (in the latter case the number of guiding devices should be increased).

If a die has an inverted cone, the blanked workpiece may be concave or convex. To eliminate this defect, the fall-through hole of the die should be ground. Another reason for such a defect may be poor fit of the knockout to the blank.

Some faults of the blanking tools, such as axial misalignment between the punch and die, excessive play in the guiding devices, parallel misalignment between the punch holder and the die shoe, etc. may cause shearing of the tool cutting edges.

Among the bending tool troubles are insufficient accuracy of the

fixing device, wrong gap between the punch and die, a shallow die, etc. These result in distortion of the workpiece shape or waviness of the bends. To remedy the troubles, fixing devices are added, the gap is adjusted, the die is deepened, etc.

When working with drawing tools, much attention should be given to the adjustment of the gap between the punch and die and selection of optimum hold-down force.

If the gap is too small, scores and bright spots appear on the side surface of the workpiece. Excessive hold-down pressure causes rupture of the metal on the cylindrical portion of the article, if the pressure is insufficient, the flange will be creased and the side surface wrinkly.

A caved bottom in a drawn piece occurs when using a punch without a vent. This defect is removed by drilling such a vent in the punch and the punch holder.

Creases on the flange and wrinkles on the walls of the drawn article may also stem from insufficient hold-down force or wrong dimensions of the blank. This defect is remedied by installing drawing ribs or using blanks of the specified size.

3. Repair of Tools

The operation wear and damage degrade the press tool performance. To maintain tools in good condition a system of repairs is established. There are routine, medium and major repairs.

Routine repair is aimed at eliminating minor defects: replacing broken parts (e.g. a stop), sharpening tool cutting edges, removing scores from guide posts, etc. Routine repair is carried out in a special section of the pressworking shop.

A foreman inspects the tool after the work and, depending on the condition, sends it either to the repair section or to a depot. Well-timed elimination of minor defects prolongs the life of a tool, while loosening of a die or punch attachment, breakage or weakening of an ejector spring that have not been opportunely detected may cause a grave breakdown of the equipment.

In the case of a *medium repair*, the tool is partially disassembled and one of its main components or several parts are replaced. Medium repairs are carried out in the repair section of the pressworking shop or in a tool maker's shop.

Major repair is usually accomplished in a tool maker's shop. The tool is fully stripped and at least a half of its main components is replaced as a rule.

The repaired tool is tested by stamping pilot lots of several tens of workpieces.

When forwarding a tool for repair, a foreman compiles a repair request form based on the inspection results or a breakdown report,

indicating the breakdown cause and the names of those responsible for it. The repair request form or the breakdown report is an authorizing document for issuing the order for repair. The order should list the tool defects to be rectified. Any design modifications may be introduced in the course of repair only on the basis of revisions introduced into the tool working drawing. If a sufficient volume of repair work is envisaged, a maintenance requirements card is compiled and repair drawings are elaborated.

The cost of repair should be cut down in any possible way. To this end, use should be made of the available tool parts since making new ones is expensive; worn-out portions of dies and punches should be replaced with inserts, cracked dies should be enclosed in holders, etc. On such occasions, there is no need for thermal treatment of parts, otherwise, in addition to the increase in labour consumption, temperature strains may result.

If a tool requires major repair and the repair cost approaches that of manufacture, it is economically feasible to make a new tool since the service life of the latter is always longer than of the repaired one.

4. Life of Press Tools

The economical feasibility of sheet metal stamping and cold die forging depends to a considerable extent on the life of the tools. The life of a tool is determined by the number of workpieces made in it before a scheduled sharpening (cutter life), before a repair (time between overhauls) and up to complete wear (service life). The longer is the life of the press tool, and the greater is the number of parts produced with it, the smaller is the tool price fraction per part and the higher is the pressworking efficiency. The tool service life is prolonged if the workpieces are simple in shape and adaptable to pressworking, the material is readily deformable and its quality is high, the tool part surface finish is good and the tool operating conditions are favourable. The working surface of punches and dies should have a surface finish of grade 8 or 9 (the USSR classification) and a sufficient hardness (HRC 54-62).

The service life of tools also depends on how they are mounted, on the press operation accuracy which should meet certain requirements, and also on the lubrication of the forming and worked surfaces. Good lubrication decreases friction thus extending the life of the punches and dies.

To prolong the life of punches and dies, their working surfaces are sometimes given special coatings, they are chrome plated, nitrided, coated with or are made entirely from hard alloys.

An approximate service life of punches and dies when working mild steel 2 to 3 mm thick is as follows: for blanking tools with punches and dies made from alloyed press tool steel—up to 600 thousand

pieces and more; if a hard alloy is used—2 500 thousand pieces and more; for drawing tools with punches and dies made from alloyed press tool steel—2 400 thousand pieces and more. The above figures may be good if applied to normal operating conditions.

Press tools equipped with hard alloy punches and dies are much more expensive than the ordinary ones. A considerably longer service life of such tools, however, not only justifies the higher cost, but on most occasions offers substantial economy.

The service life of tools for cold extrusion and upsetting is one of the decisive factors in determining the feasibility of implementing such operations. To increase wear resistance of these tools, special investigations are carried out to optimize the geometry, various shrouds and efficient lubricants are used, the pressworking process is divided into steps to ensure optimum strain values, etc. Decrease of the specific force when dividing one step into two may prolong the service life of a tool by several times.

The material of punches and dies as well as its thermal treatment conditions influence greatly the tool life. Insufficient hardness or residual austenite present in steel drastically decreases the service life of the tools. The degree of wear of punches and dies is also dependent on the lubrication of blanks. Phosphatizing and soaping with the use of molybdenum disulfide additive contribute to wear resistance. As proved by experience the service life of extrusion and upsetting punches is extended by several times when molybdenum disulfide is present in a thin phosphate layer.

Review Questions

1. What is the procedure for mounting small and medium-size press tools?
2. How are the tools removed from the press?
3. How are large tools installed on the press?
4. Outline the kinds of press tool repairs.

Chapter XII

PRESSWORKING TECHNOLOGY

1. Adaptability of Workpiece to Pressworking

A pressworking process comprises operations for preparing the material (cleaning, lubrication), making blanks (blanking of sheets and strips), deforming operations (shearing, forming), heat treatment (intermediate annealing to relieve machining strain, hardening and tempering to impart the required properties), finishing opera-

tions (shaving, deburring, washing, painting, applying decorative coating, etc.). Assembly and welding or gluing operations may be also included in the pressworking process.

A process should also comprise quality control operations for checking dimensions and quality of preforms and finished parts.

Prior to elaborating a process for making a part, the product engineer should check the latter for technological effectiveness, i.e. determine what a combination of the part structural elements, material and quality will make its manufacture most simple and cost cutting without degrading the performance.

A part material should have physical and mechanical properties suitable for the part application and be as easily workable as possible. A production process is elaborated with a view to using the cheapest material and minimizing its consumption. To decrease consumption of metal in sheet metal stampings, use is made of stiffening ribs which allow a decrease in the material thickness without impairing the part strength or rigidity, various ports are punched in the parts while the resulting scrap is employed for stamping other components, the rigidity of sheet part edges is increased by beading, etc. The product engineer and designer strive to increase the stamping rounding radii, thus diminishing the number of pressworking operations and extending the tool life; eliminate sharp corners to achieve the same results; introduce notching in the internal corners of bent workpieces, thus precluding cracks in bending with a preset radius; alter the part shape, if possible, to ensure scrapless blank layout, etc.

The technological effectiveness of a stamping should be analyzed taking account of local production conditions and lot size.

In mass production, the main characteristics of stamping technological effectiveness are the material consumption and labour input. The labour input can be decreased by combining operations, employing sophisticated automatic tools, presses and transfer lines. Additional investments involved in automation exert but minor effect on the production cost since they are distributed among a great plurality of stampings.

In small-lot production, the price of a tool has a considerable influence upon the production cost. In this case it is economically feasible to use multi-purpose tools with replaceable punches and dies and to divide the process into a number of separate simple operations. Relatively simple punches and dies substantially cut the price of tooling.

2. Process Design

A pressworking process design involves the analysis of a part technological effectiveness: study of the shape, dimensioning, volume of production, workability of the material, elaboration of the shape

and sizes of the blank; selection of the material pre-treatment methods, heat treatment conditions; definition of pressworking operations and steps; designing of press tools and selection of the pressworking equipment, mechanization and automation means.

A product engineer designing a process for pressworking of parts analyzes the possible variants of part manufacture. He usually selects the variant which ensures minimum production costs. The production potentialities and equipment available should be also taken into account.

The stamping design data are taken from the article drawing. When designing a process, the part construction is sometimes altered to decrease labour input, material consumption and wear of tools. When a part is designed, the possibility of making it by pressworking should be considered. Therefore, the best results are achieved by the team work of an article designer, product engineer and tool designer.

Changes in the part design often allow the use of scrapless stamping and simplification of the tool construction. When replacing machining with cold die forging, it is necessary to analyze the shape of the parts which were adapted to cutting operations, cutting tool designs and metal-cutting machine potentialities. Small radii of rounding, grooves and other structural features are frequently dictated by the adaptation of the part to cutting rather than by the part operating conditions.

After the dimensions and shape of the blank are determined, the type and size of stock (sheet, strip, bar) are selected.

Flat parts are stamped by separate, progressive, compound and progressive/compound tools. In the first case each operation (shearing, blanking, punching) is performed in a separate tool. With progressive stamping one and the same tool is used to perform several operations while the material is transferred from one tool station to another. A compound tool ensures blanking and punching during one stroke of the press without shifting the material.

For instance, to manufacture a washer, the following variants can be used: punching and blanking in a single- or multi-row compound tool or punching and blanking (the first operation) in a single- or multi-row progressive tool followed by straightening (the second operation) on an automatic press or special machine.

When stamping bent or hollow parts with holes, provision is made for cutting, forming (bending, drawing, etc.), trimming, piercing, shaving, etc. If the part accuracy requirements are high, sizing is employed.

Examples of designing the forming steps in the manufacture of intricate parts from sheet blanks are given in Figs. 167, 168. Figure 169*a* to *e* illustrates the forming steps for cold die forging of a hexagonal cap.

A sophisticated use of metal in cold die forging is exemplified in Fig. 170. The process ensures simultaneous production of three parts. A cylindrical blank (Fig. 170*a*) is upset (*b*), next follow a reverse extrusion (*c*), combined extrusion (*d*), punching of the bottom and blanking (*e*).

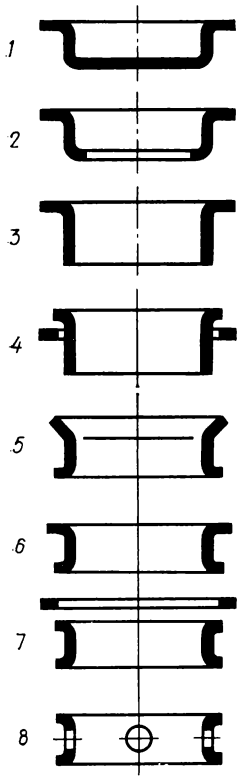


Fig. 167. Bearing cage pressworking steps
1—blanking and drawing; *2*—piercing bottom; *3*—flanging; *4*—first flange allowance trimming; *5*—flanging through 45°; *6*—flanging through 90°; *7*—second flange allowance trimming; *8*—piercing holes

Examples of parts produced by cold die forging on multi-station upsetting machines are given in Figs. 171*a* to *e*, 172*a* to *e*, 173*a* to *e*.

When forging a semi-hollow spherical pin (Fig. 171), the cylindrical blank (*a*) is reduced (*b*), headed (*c*), then a cavity is formed in the head (*d*) and the spherical head is finally shaped with a simultaneous reduction of the stem for threading. The capacity of the automatic machine is 60 to 70 pins per minute.

A chuck wrench is forged from a cylindrical blank (Fig. 172*a*) in four steps: upsetting the rod (*b*), heading (*c*), forming the gear rim with flash (*d*) and trimming the flash (*e*). The capacity of the automatic machine is 120 to 130 wrenches per minute.

When forging a flanged plug (Fig. 173), the blank (*a*) is first upset in a closed die with a pilot depression made for forming the hollow (*b*), then the hollow is formed (*c*), the hexagonal head for the wrench is preformed (*d*) and at last the hexagonal head with a flange is finally shaped (*e*). The capacity of the machine is about 80 plugs per minute.

A process for the production of union nuts is described below. Such nuts were formerly manufactured on automatic lathes. To increase the metal utilization factor and cut down the cost, these mass products were adapted to cold die forging technology. The theoretical studies and experimental work performed revealed the expediency of making union nuts from hexagonal piece blanks.

The pressworking steps and the basic dimensions of the preforms and finished articles are given in Table 4.

Piece blanks are made on a cold upsetting single-strike automatic machine from cold-drawn hexagonal coil stock. The hexagonal stock for 17- and 19-mm nuts is obtained by one-pass drawing on a drawing mill from hot rolled bars of 18 and 20 mm in diameter. Work hard-

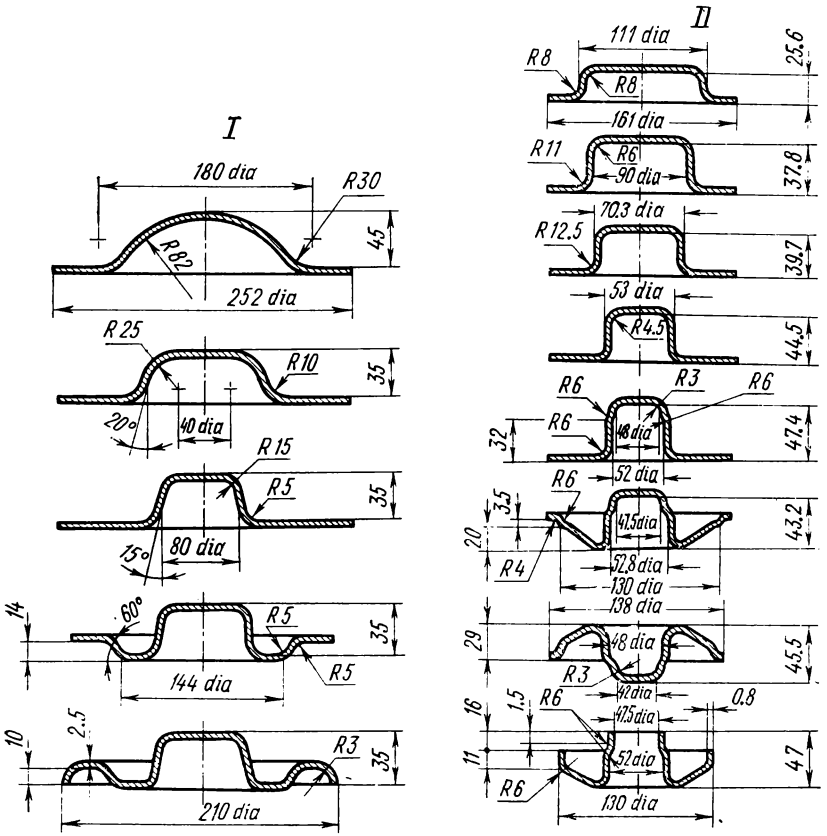


Fig. 168. Examples (*I*, *II*) of designing pressworking steps for making intricate parts

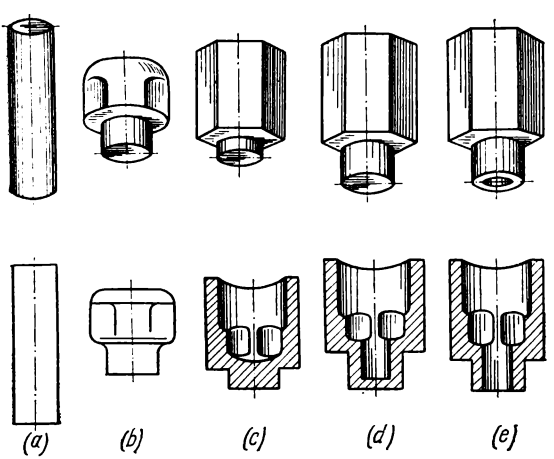
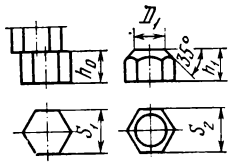
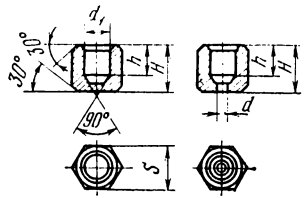


Fig. 169. Cold die forging of a hexagon head (*a*) blank; (*b*, *c*, *d*) extrusion steps; (*e*) punching and facing

Table 4

Steps of Union Nut Cold Die Forging
(all dimensions are given in mm)

Equipment	Sketch	Symbol	17-mm hex		19-mm hex	
			M14×1.5	2M14×1	M16×1.5	M16×1
Cold upsetting single-strike automatic machine PKZ-1		h_0	10.6	6.4	8.9	5.9
		S_1	16	16	18	18
		D_1	12.5	12.5	14.5	14.5
		h_1	$9.2^{-0.2}$	$6.7^{-0.2}$	$9.2^{-0.2}$	$6.2^{-0.2}$
		S_2	16.5	16.5	18.5	18.5
Vertical single-action crank press PKE-10		d_1	12.376-12.716	12.918-13.118	14.376-14.716	14.918-15.118
		h	13	9.5	11.5	9.5
		S	$17^{-0.24}$	$17^{-0.24}$	$19^{-0.24}$	$19^{-0.24}$
		D	16.2	16.5	18.1	18.7
		H	16	11.5	15.5	11.5
		d	8.2	7	10.2	9

ening involved in drawing improves the accuracy and quality of blank cutting.

On a cold upsetting single-strike automatic machine the stock is fed by shaped rollers to a hexagonal shearing die *1* (Fig. 174) to

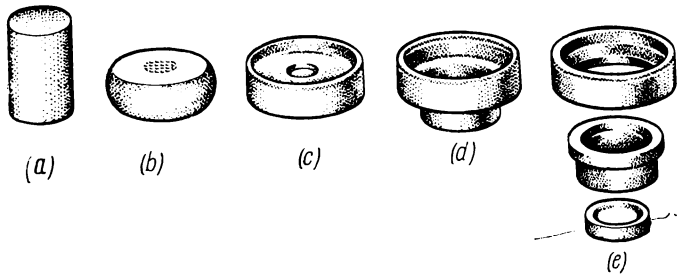


Fig. 170. Example of sophisticated utilization of metal in cold die forging (*a*) blank; (*b-e*) forging steps

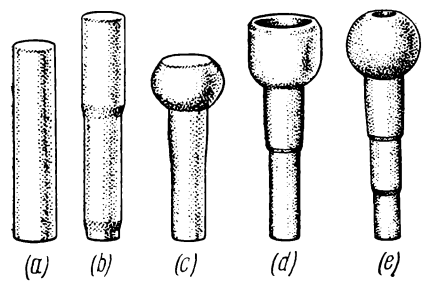


Fig. 171. Steps of forging a ball pin on a four-station automatic header (*a*) blank; (*b-e*) forging steps

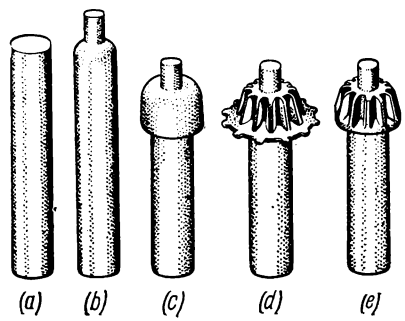


Fig. 172. Steps of cold die forging of a chuck wrench (*a*) blank; (*b-e*) manufacturing steps

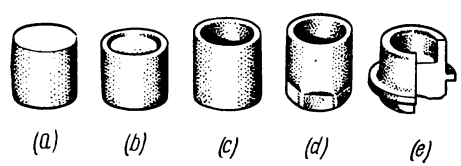


Fig. 173. Blank (*a*) and manufacturing steps in cold die forging of a flange plug (*b-e*)

thrust against stop *2* (the hexagonal stock should be coiled facewise since the edgewise coiled stock will not enter into the shearing die). Shearing blade *3* shaped to fit the stock profile cuts measured blank *4* and transfers it with the stop to the upsetting station where the

stop actuated by the follower pushes the blank in upsetting die *5* having a hexagonal working cavity. The die is oriented in holder *6* by key *7*; knock-out *8* doubles as an adjustable stop. Hexagonal punch *9* secured in a collet punch holder upsets the blank and forms a pilot chamfer of 35° which is needed to make an entry chamfer in the thread hollow of the nut. The punch stroke is constant and its initial position is adjusted by means of a wedge.

The upset blanks are washed and annealed to a hardness of not above HB 137 in a belt-type controlled-atmosphere furnace. The

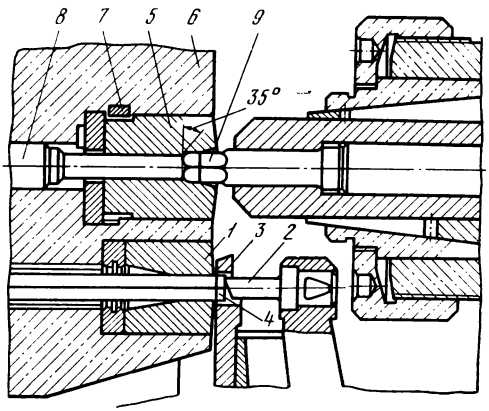


Fig. 174. Diagram of upsetting on a single-strike automatic header

annealed blanks are tumbled in drums to remove scale and upsetting flash. The tumbled blanks are phosphatized in zinc monophosphate with subsequent impregnation with soap emulsion and hot air drying.

The preforms are then loaded into the bin of a vertical single-action crank press having two slides with independent shutheight adjustment. The blanks oriented in the tilted pocket-type bin are fed to inclined chute *1* (Fig. 175) and are then moved by gate *2* to grips *3* of dial *4* which transfers the blanks to a two-station tool for extruding.

The tool is distinguished for reliable axial alignment between the punches and dies, which is achieved by installing them in a common stationary block (Fig. 176) fastened to the press bed. The block has a slot for transfer of the blanks from one station to another by means of the dial grips.

Quills *1* and *2* of punches *3* and *4* move in bronze bushes *5* and *6* which are secured in the upper part of the block, thus ensuring high-precision motion of the quills (punch holders) *1* and *2* irrespective of the condition of press slide guides. The quill ends are provided with collars whereby they are retained in the T-slots of the press

slides. When the press slide moves upward, preform *7* is shifted by knock-out *8* to the grips of the dial (Fig. 175); when the slide moves down, the dial indexes to transfer the preform to the hole punching

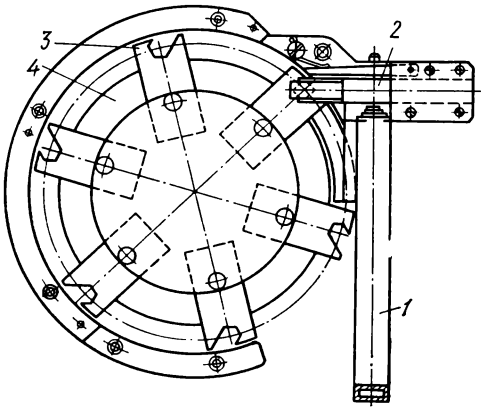


Fig. 175. Blank feed for a two-station tool

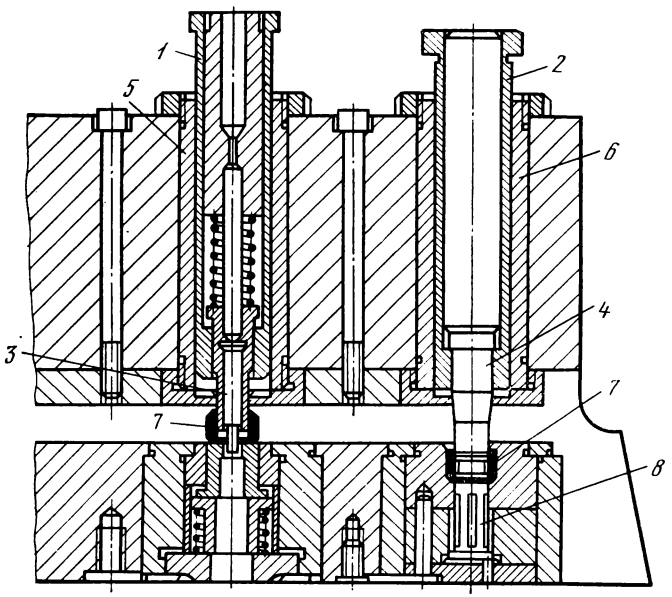


Fig. 176. Diagram of extrusion and punching of union nuts in a two-position tool

station. Piercing punch *3* moves jointly with a spring-loaded guide bush which centres the preform so as to provide accurate alignment of the nut thread hollow with the hole in the bottom.

The formed nut with a hole punched in the bottom is withdrawn from the tool by the dial and ejected from the grips into a container.

The press is equipped with an interlock device which disengages the drive in the case of a punch failure or incomplete indexing of the dial.

The tool block has dove-tail slots for mounting on the press bed and is secured by means of a detachable eccentric clamping with a handle. Such an attachment considerably simplifies and accelerates tool replacement.

The dies for a cold upsetting machine and crank press are made from tool steel У10А; their cavities are formed with heating the blanks to 600-700°C followed by stream hardening to HRC 60-62. The dies made from vanadium steel offer a service life 2-2.5 times as long as those made from steel У10А; this is attributed to 0.2-0.4 per cent of vanadium in steel, which deepens hardness penetration and increases hardness of the sublayer.

The upsetting punches are made from steel X12M hardened to HRC 58-60; the life of such punches is from 7 to 8 thousand blanks. Punches for cold extrusion are made from steel P6M5 hardened to HRC 60-62; their life is 4 to 5 times as long as that of the X12M steel punches and reaches 25 to 30 thousand parts.

Substitution of metal cutting on automatic lathes with cold die forging in the production of union nuts decreases the labour input by 25-45 per cent and increases the metal utilization factor from 41-51 to 87-90 per cent with simultaneously improvement of the nut strength.

The improvement in strength provides for replacing steel A12 with cheaper steel 10кп.

Expenditure rating. Consumption of metal for the manufacture of one part is calculated from the part drawing. The metal loss and waste involved in the selected production process are taken into account.

Selection of the optimum size of a blank is a decisive factor of metal economy. When designing a process, a number of blank layout and stock size variants are calculated to find out the one with the minimum consumption of metal.

Selection of a press. The main characteristics of a press are its force, work, stroke, number of strokes per minute, bed and slide dimensions, shutheight.

The selected press should have a rated force above the calculated pressing force, a shutheight which permits mounting of the specified tool, a stroke providing for the feed of blanks and removal of workpieces and a sufficient speed of action to ensure high productivity.

The press design should be adapted to the installation of safety and automatic feeding devices. The press force and work are also taken into account.

Crank press certificates usually contain diagrams of the permissible force which is determined by the crankshaft strength. When selecting a press according to the force, the curve of the force required for performing a given operation is compared with the permissible force curve. The press suits for a given operation if the required force curve does not fall beyond the permissible force curve. Such a comparison is resorted to when designing forming operations requiring a long stroke of slide, as in deep drawing. In the case of blanking or punching the press is selected only by its rated force value.

In addition to the permissible force check, a press suitability for a given operation is checked for work. A press power (in crank presses it is assumed to be equal to flywheel kinetic energy) should exceed the total work spent in the given operation, for friction, press deformation, compression of knock-outs, strippers and dampers.

If the press is overloaded, the flywheel speed decreases and the electric motor gets damaged.

Review Questions

1. What is the technological effectiveness of a part?
2. Describe the procedure of designing a cold pressworking process.
3. What are the criteria for selecting a press?

Chapter XIII

FINAL AND FINISHING OPERATIONS

The final and finishing operations of pressworking technology include heat treatment, pickling, washing, drying, tumbling, painting, varnishing, polishing, enamelling, etc.

1. Heat Treatment

Heat treatment is used to ensure the required structure and mechanical properties of the material to be worked. It is performed before pressworking if the metal structure and mechanical properties are unfavourable for pressing, in the course of pressworking to relieve strain hardening, or after it to impart the required structure and properties to the workpiece metal.

Prior to heat treatment the preforms or blanks are thoroughly cleaned of oil and other contaminants that would otherwise burn during heat treatment thus impairing the metal surface finish.

Heat treatment resides in heating a metal to a certain temperature, exposing it to said temperature for a certain time and then cooling

down at a certain rate. It changes the structure, and hence the properties of metals. The changes in the structure of a metal or alloy follow a particular mechanism which can be represented by the so-called constitutional diagrams. Such a diagram for an iron-carbon alloy (i.e. for steel or pig iron) is shown in Fig. 177. In this diagram, line *ABC* indicates the boundary of the appearance of first crystals in the molten metal as it cools down. Above the line the metal is in a molten state.

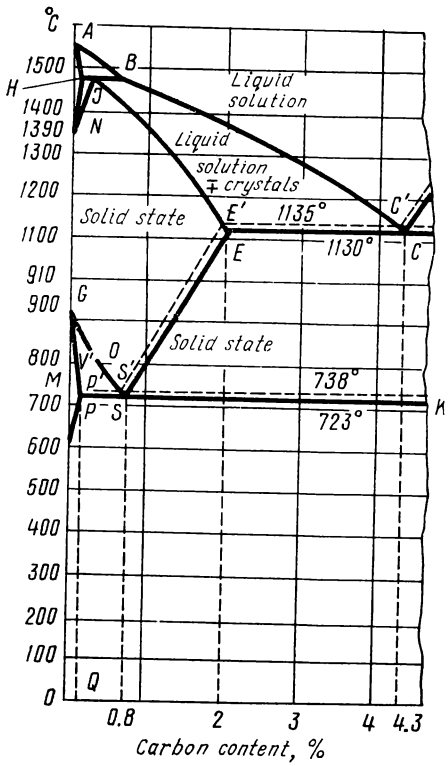


Fig. 177. Iron-carbon constitutional diagram

The completion of the solidification process is shown by line *AHJEC*; below it the metal is solid. The other lines indicate the boundaries of the internal structure rearrangement (phase changes) of the metal during heating and cooling.

The main types of heat treatment operations are annealing, normalizing, hardening and tempering.

Annealing is heating steel 30-40 deg C above line *GSE* (Fig. 177), keeping at this temperature and slowly cooling together with the furnace. Such a "full" annealing is used to obtain fine-grain structures, restore physical and chemical properties after cold pressing and to relieve residual stresses.

In addition to full annealing there are partial and lowly annealing.

Partial annealing is heating steel to 750-760°C followed by slow cooling. This relieves the internal stresses, somewhat changes the structure and slightly improves machinability of steel.

In low annealing, steel is heated to 650-680°C and then slowly cooled. Its purpose is to relieve some of the internal stresses in the metal and make it a little harder.

Normalizing is heating steel to 30-50 deg C above line *GSE*, keeping it at this temperature and then cooling in the air. Normalizing restores physical and mechanical properties of steel, eliminates

strain hardening and prepares the metal structure for final heat treatment. The hardness and impact strength of normalized steel are well above those of the annealed one. In normalizing the metal is cooled in the air, therefore normalizing is a more rapid, hence a more efficient, process than annealing. Thus, it is expedient to subject carbon steels to normalizing instead of annealing.

Annealing and normalizing are called *bright* when they are carried out in furnaces with controlled atmosphere which prevents scaling of the surface of the metal being treated.

Hardening of steel consists in heating it to a temperature 30-40 deg C above line *GSK* and then rapidly cooling (quenching) in water or oil. Hardening is used to increase hardness, strength and wear resistance of parts. The forming parts of press tools, vital components of machines, various cutting tools, etc. are subject to hardening.

The metal properties after hardening depend on the temperature and rate of heating, exposure time and cooling rate. The heating rate depends on the type of the furnace, shape of the parts and their arrangement in the furnace. The permissible heating rates which prevent hardening cracks in metal are indicated in reference books.

To quench steel parts, use is made of water, aqueous solutions of salts, molten salts and mineral oils. The quenching medium is selected depending on the chemical composition of steel and the properties to be obtained. Water-hardened steel offers higher hardness than oil-hardened steel.

Steels containing less than 0.3 per cent of carbon cannot be hardened since their low carbon content does not provide for the necessary structural changes. If parts made from such steels are to have an increased surface hardness, they should be first case-hardened (i.e. their surface saturated with carbon), and then hardened.

Quenching is accompanied by the formation of the so called steam jacket which envelopes the part, thus slowing down the steel cooling rate and decreasing hardness penetration. Therefore, it is recommended to move the parts in the horizontal and vertical directions continuously when quenching them in water.

The main methods of hardening are single-step hardening, two-medium hardening, stream hardening, temper hardening, etc.

Single-step hardening is the simplest and most common method wherein the parts are kept in one quenching medium up to complete cooling. Carbon steel parts are usually quenched in water, alloy steel parts, in oil. In *two-medium hardening* the parts are first cooled in water and then in oil. This operation can be accomplished only by skilled workers.

In *stream hardening* the heated parts are cooled by a stream of water. This method is usually employed in the case of hollow workpieces to avoid the formation of a steam jacket in the hollows. Rapid cooling ensures high hardness of parts.

To harden impact tools in which hardness should uniformly and gradually decrease from the working portion towards the core, use is made of *temper hardening*. In temper hardening the parts are not kept in the quenching medium up to complete cooling; instead they are withdrawn at a particular moment to preserve heat in the part core, sufficient for self tempering.

There are a plurality of machine parts that are to have high surface hardness, wear resistance and simultaneously withstand heavy impacts, i.e. be not brittle. Such a combination of properties is achieved by using surface hardening. Induction hardening, flame hardening and electrolyte quenching are most widely used for surface hardening of machine parts.

In high-frequency current heating, eddy currents are induced in the metal; they are not uniformly distributed throughout the part cross section but concentrate near the surface so that the surface layers are rapidly heated to a high temperature while the core is slightly heated only due to heat conduction of steel. The induction heating is carried out in special apparatuses called induction heaters.

Tempering (low-, medium- or high-temperature) is aimed at reducing the internal stresses resulting from hardening, obtaining the stable structure and stable properties of the metal. Low-temperature tempering consists in heating steel to 150-200°C followed by cooling. It is used mainly with tool steels which must be very hard and wear resistant.

Low-temperature tempering is employed, say, for treating bearing races, balls and rollers. *Medium-temperature tempering* is applied to machine parts which must combine high hardness with good elasticity (leaf and coil springs, etc.). This involves heating steel parts to 350-450°C. *High-temperature tempering* (between 500 and 650°C) is used with machine parts that must have adequate strength and ductility, i.e. parts made from structural steel. Hardening followed by high-temperature tempering is sometimes referred to as toughening. The mechanical properties of toughened steel considerably surpass those of annealed and normalized ones. The parts intended for operation under adverse conditions are subjected to toughening.

Some stresses remain in the hardened parts after tempering. They are spontaneously relieved at room temperature during a prolonged period of time. Such a natural ageing is accompanied by changes in the part dimensions and shape. To prevent changes of part dimensions in service, use is made of artificial ageing consisting in heating of parts to 100-150°C and keeping them at this temperature for 18-35 h. Artificial ageing brings about no substantial changes in the hardness or internal structure of the hardened parts.

On some occasions the hardened parts are subjected to cold treatment for decreasing the amount of retained austenite which decreases the hardness of steel parts and causes changes in the dimensions at

spontaneous decay. The hardened but not tempered parts are placed in cooling chambers and cooled to a temperature of —12 to —120°C.

Heat treatment equipment. The main equipment for heat treatment includes heating furnaces, induction heating installations, salt baths and quenching tanks. The modern heating furnaces are

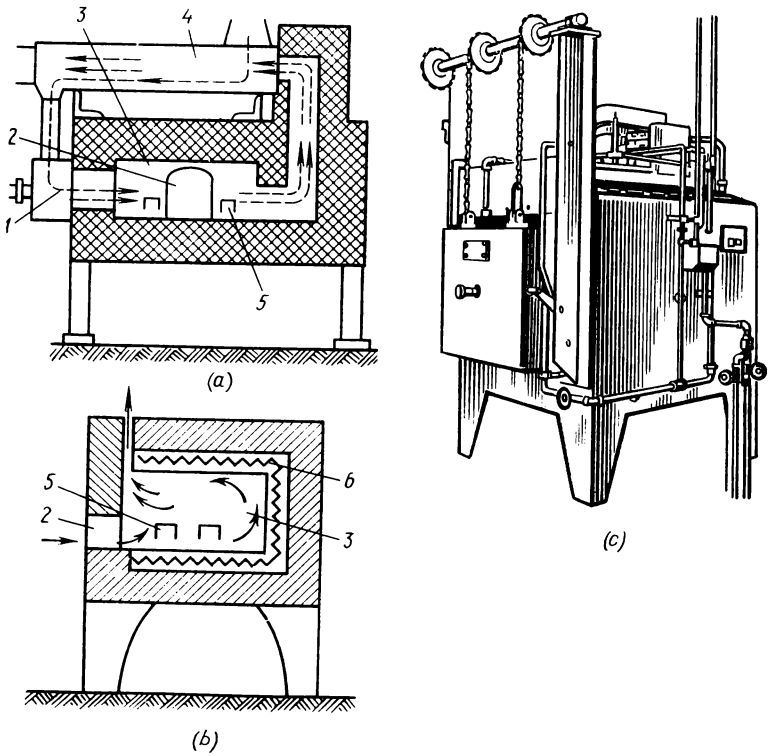


Fig. 178. Compartment furnaces
(*a*) diagram of a combustion furnace; (*b*) diagram of an electric furnace; (*c*) general view of a compartment furnace; *1*—gas burners; *2*—charging port; *3*—heating chamber; *4*—recuperator; *5*—blanks being heated; *6*—electric heaters

sophisticated apparatuses equipped with means for mechanized loading and unloading and with automatic devices for controlling and adjusting the temperature and composition of the furnace atmosphere.

The heating furnaces are divided according to the technological feature (for hardening, annealing, tempering), design (compartment or continuous furnaces) and the source of heat (petroleum, gas and electrical furnaces). All these furnaces have metal frames and are lined inside with refractory bricks.

In *compartment furnaces* (Fig. 178*a*, *b*, *c*) the metal is heated at a constant temperature. The chamber is heated by combusting fuel or with the use of electric resistance heating elements. In continuous furnaces the blanks are heated while moving through a long chamber. The chamber is heated by combustion gases or electric heating elements.

The blanks are moved through the furnace space by a conveyer or pusher. The temperature in the working space of this furnace is not uniform; it gradually increases towards the outlet. In high-frequency current heating the blanks are pushed through an induc-

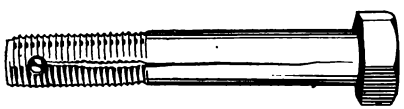


Fig. 179. Hardening crack

tion heater. Such heaters usually operate in the automatic mode and heat the blank during several tens of seconds.

The most frequent defects encountered in heat treatment are as follows: hardening cracks, deformation and warpage of parts, oxidation, decarburization, overheating, burn, underheating, etc.

Hardening cracks (Fig. 179) are formed, as a rule, at too rapid cooling or heating and cannot be remedied. Deformation and warpage of parts stem from non-uniform heating and cooling of metal. Depending on the shape and dimensions of blanks, use is made of different methods of their immersion into the quenching tank and also of various appliances which ensure uniform heating and cooling of parts.

Flame and electric heating in furnaces usually takes prolonged time and is accompanied by the oxidation of metal, i.e. scaling and decarburization of the surface layer. *Scaling* causes burning loss of metal reaching 1.5 to 3.0 per cent and more of the amount of metal being heated. Scaling distorts the part shape and the part surface under scale gets rough. The parts are descaled by pickling or shot blasting.

Decarburization, i.e. *burning out of carbon* from the part surface, occurs at steel oxidation and drastically decreases the part strength. To prevent burning loss and decarburization of metal, use is made of scale-free heating in furnaces with a protective atmosphere of gas mixtures.

Overheating of steel leads to quick growth of grains. Overheated steel features reduced plasticity and is more liable to cracking in hardening. Overheating is rectified by annealing or normalizing.

Burn (unreclaimable spoilage) stems from excessive exposure of metal to a high temperature. In this case grains are oxidized and

sometimes even melt at boundaries, the metal loses plasticity and becomes brittle.

Underheating results in low hardness of parts. This defect is corrected by annealing with subsequent hardening.

2. Thermochemical Treatment

To increase the surface hardness and wear resistance of steel parts, and to improve their anti-corrosion properties, use is made of thermochemical treatment which includes: carburization, nitriding, cyanide hardening, etc.

Carburization is saturation of the steel surface layer with carbon; it is used with carbon and alloyed steels having a carbon content of up to 0.3 per cent. The steel parts to be carburized are packed in boxes filled with a material (carburizer) capable of giving up carbon readily—powdered charcoal, special gas mixtures, etc. The parts are heated in such a medium to 850-950°C and are kept at this temperature without admission of air for several hours. To ensure the required surface hardness after carburizing, the parts are normalized, hardened and tempered.

Nitriding is saturation of steel surface layer with nitrogen to increase hardness. It is accomplished in special furnaces at a temperature of about 550°C. Gaseous ammonia is fed to the furnace; the ammonia dissociates and gives off atomic nitrogen which reacts with the metal and forms nitrides of great hardness. Nitriding is usually applied to special grades of steel containing chromium and aluminium (38ХЮ), chromium, molybdenum and aluminium (38ХМЮА) or chromium, tungsten, vanadium and aluminium (38ХВФЮ) and some others.

Nitrides of chromium, molybdenum, vanadium are very hard. Nitriding carbon steels is not advisable, since iron nitrides do not give a high hardness and the surface layer becomes very brittle.

Cyanide hardening is a process whereby both carbon and nitrogen are introduced into the steel part surface simultaneously for obtaining high surface hardness after hardening. It is used with carbon, alloyed and high-speed steels. The most common technique is liquid cyanide hardening wherein the parts are immersed into molten cyanides. The depth of liquid cyanide hardening may reach several tenths of a millimetre.

Liquid cyanide hardening is very dangerous since cyanides are poisonous. After working around cyanide baths, it is necessary to wash hands carefully, never eat in the work premises or in dirty overalls. Parts to be immersed in the cyanide bath must be dry to avoid splashing out of molten salts by the steam of instantaneously boiling water.

Cyanide hardening can be also carried out in a solid or gas medium.

Other methods of thermochemical treatment of steel parts include saturation of the surface layer with chromium (chromizing), aluminium (aluminizing), etc. These processes are termed surface impregnation; they increase the steel part resistance to corrosion, heat and wear.

3. Preparation of Surfaces

The life of a paint and varnish or other coating on a part depends greatly upon the condition of the surface to which said coating is to be applied. Therefore, operations for preparing surfaces for coating receive particular attention in the production processes (including the pressworking ones). Depending on the shape of parts and the

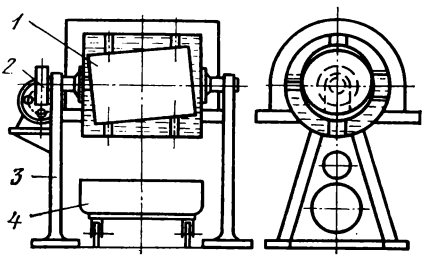


Fig. 180. Diagram of a noiseless tumbler
1—barrel; *2*—reduction gear; *3*—frame; *4*—container

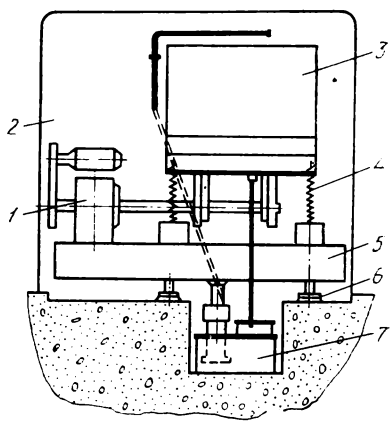


Fig. 181. Diagram of a vibration tumbler
1—drive; *2*—soundproof casing; *3*—working chamber; *4*—spring; *5*—frame; *6*—shock absorber; *7*—sediment tank

properties of the material, use is made of mechanical, chemical, electrochemical and other methods of surface preparation.

The mechanical methods include hydroblasting, abrasive and electrohydraulic cleaning, shot blasting, tumbling, etc. Of these, hydroblasting shot and synthetic corundum blasting and tumbling are used most frequently.

In hydroblasting, the parts are treated with a mixture of an abrasive with water fed under pressure from a jet device. The mixture can also consist of regular sand, metal shot and synthetic corundum.

Tumbling is aimed at removing flash after cutting operations of pressworking, rounding off sharp edges, removing traces of corrosion and scale from small parts. The process resides in the rela-

tive displacement of blanks and cleaning medium in a revolving drum. To improve the cleaning effect, the cleaning drum is filled with different mixtures: sawdust, abrasive powders, crushed glass, etc. To decrease noise, the tumbers (cleaning drums) are made with double walls and oil is filled in between (Fig. 180).

There are dry and wet tumbling techniques. Wet tumbling is used less frequently, mainly for intricate-shape non-ferrous parts. It is accomplished in perforated drums immersed into a liquid medium.

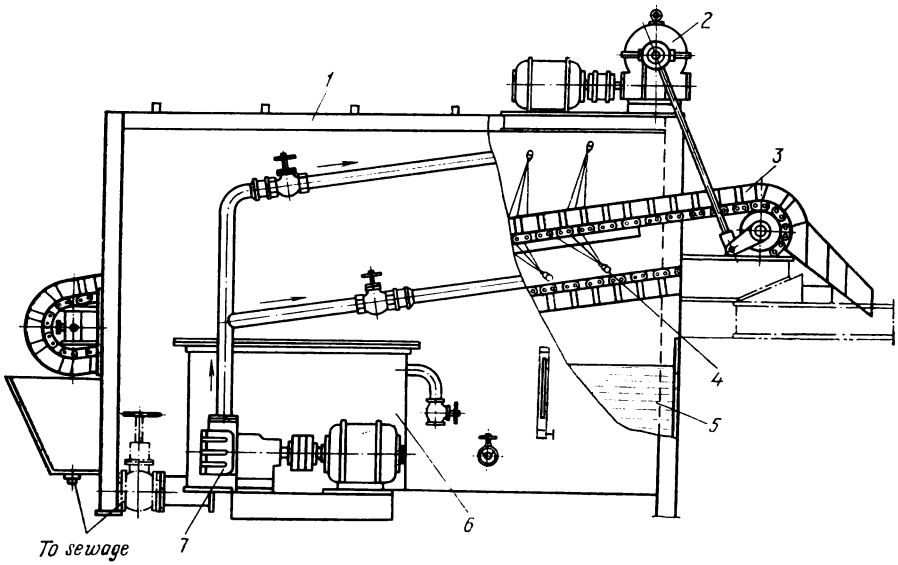


Fig. 182. Diagram of a conveyer washing machine
1—water-tight casing; *2*—electric motor; *3*—conveyer belt; *4*—nozzles; *5*—tank; *6*—tank with a filter; *7*—pump

A very efficient and universal cleaning process is vibration tumbling. The part to be tumbled is moved in different directions relative to specially shaped abrasive particles which treat both the inner and outer surfaces of the part. The parts are not exposed to impact loads so that thin-walled components may be vibration tumbled.

The working chamber of a *vibration tumbler* (Fig. 181) is oscillated by means of an eccentric mechanism driven from an electric motor. The oscillation frequency is 1 400 to 2 000 oscillations per minute, the amplitude is from 3 to 4 mm. Vibration tumbling cuts the cleaning time by 1.5-2 times as compared with ordinary dry tumbling.

As regards chemical methods of cleaning, degreasing and pickling have found widest application. Degreasing is effected with solvent or aqueous detergents. To remove oil and contaminants from

blanks, before pressing, heat treatment and after pressing, use is made of *pickling*.

Salts, pickling solution residues, quenching oil traces, etc. are removed by washing in hot water or alkaline solutions. This operation is carried out in washing machines. *A conveyer washing machine* is shown in Fig. 182. The parts are continuously moved by conveyer belt *3* inside watertight casing *1*. Hot solution is fed under pressure from pump *7* through nozzles *4*. The conveyer is driven from electric motor *2*.

Small-size parts which require high-quality cleaning are treated in ultrasonic installations.

Such installations are used for cleaning and degreasing small components of radio and TV sets, various instruments, etc. Ultrasonic cleaning ensures removal of dirt from hard-to-reach cavities of parts. The labour input is decreased drastically as compared with other methods of cleaning. If the parts are very dirty, it is good policy to clean them first with a stream of liquid or compressed air and then subject to ultrasonic cleaning.

4. Finishing Operations

Depending on the design of a part and scale of production, stampings are painted by different methods: spraying, dipping, or flow coating. Spraying is the most common technique. Spraying may be airless or effected by air pressure. In air pressure spraying, compressed air and paint are supplied from the atomizer at different velocities. The air flow velocity is thousands of times as high as the paint velocity so that minute paint droplets are formed and stick to the surface being coated. In airless spraying paint is fed from the atomizer under a high pressure without the use of compressed air.

Electrostatic spraying finds extensive application. This method is based on interaction of high-voltage electric fields and charges. It ensures high-quality coatings, cuts consumption of paintwork materials, simplifies automation of paintworking. However, electrostatic spraying cannot be used for intricate-shape parts with deep hollows.

In *dip painting* the part is immersed into a tank with paint, withdrawn from it to remove excessive paint and dried. The dipping process can be fully mechanized. Despite its simple equipment and adaptability to mechanization. this method has grave shortcomings such as the impossibility to use quick-dry paints or apply thick coats, the excessive consumption of paints, etc.

Electrodepositing painting is more efficient. The part to be painted and the bath (or special electrodes) are connected to unlike poles of a dc source and the paint is electrically deposited. This method ensures high-quality coatings of adjustable thickness, high productiv-

ity, considerable improvement of labour conditions, better fire safety. However, it is suitable only for water-thinned paints, which restricts the sphere of its application.

Flow coating is accomplished both with and without the use of electric current. This method is money-saving but cannot ensure high-quality decorative coatings.

In small-batch production the parts are painted on stands or in special chambers; in large-batch and mass production, in automated conveyer-type installations.

The painted parts can be dried both at an ambient temperature (*natural drying*) and with the use of special equipment (*artificial drying*). The protective and operation properties of a great number of coatings considerably depend on the conditions of drying. Artificial drying is performed in special drying chambers. Electric heaters, reflector lamps and other devices are used for drying.

Polishing is intended to decrease the roughness of part surfaces for subsequent varnishing or electroplating (chromium, nickel, etc.). Polishing is carried out on special machines on polishing bobs coated with a thin layer of polishing paste. In addition to mechanical polishing, ultrasonic, electrochemical and other methods of polishing are employed.

In ultrasonic polishing the part is immersed into a bath with liquid solution containing abrasive dust. The ultrasonic vibrator arranged in the bath directs the abrasive dust particles suspended in the liquid to the surface of the part. The abrasive particles polish the surface.

Electroplating (chromium-, nickel-, zinc-plating, etc.) is intended to protect parts against corrosion and decorate their surfaces. Electroplating is carried out in special electroplating vats.

Enamelling is widely used in the production of tanks, flasks and other domestic items. The formed parts are pickled, washed and dried and are then enamelled in special baths or chambers.

Review Questions

1. List the main types of heat treatment.
2. How is the case hardening of steel carried out?
3. Describe methods of surface preparation for coating.
4. What methods of part painting do you know?

Chapter XIV

QUALITY CONTROL OF STAMPINGS AND FORGINGS

1. Fundamentals of Quality Control at Enterprise

When designing a pressworking process, provision is necessarily made for quality control operations. Quality control in cold pressworking shops involves incoming material control, inspection of press tool mounting and adjustment before pressworking, control of preforms and product inspection.

Product inspection is carried out by the press operators and inspectors of the plant quality control department (QCD).

The head of the plant QCD is subordinate directly to the plant director. The QCD includes sections for accepting incoming materials, preforms and vendor items, shop quality control sections at all blank preparation, machining and assembly shops, and also an engineering section with reject analysis teams. The shop quality control sections are headed by chiefs who are subordinate directly to the head of the plant QCD or his deputy. Senior quality control foremans are responsible for quality during their shifts. Subordinate to them are quality control foremans of shop sections, bays, transfer lines and quality inspectors supervised by them. The QCD staff is independent from the shop management and production and engineering services of the plant.

The modern organisation of production presupposes unconditional responsibility of each employee for product quality. The QCD inspectors thoroughly analyze all the factors of the production process and effect preventive inspection to preclude low-quality products.

The press operators and foreman should necessarily check the workpieces or preforms before presenting them for inspection by the QCD staff. If a QCD inspector traces defects in a lot of parts during acceptance, the entire lot is returned to the worker.

The number of quality control operations in the course of manufacture depends on the shape and dimensions of the part, the required accuracy and surface finish. The more complex the production process, the more frequent should be the checks of half-finished products. The inspection frequency also depends on whether the parts are produced by a straight-line flow method or with prolonged intervals between separate operations. In the first case, operation checking is performed only when adjusting the press tools and at the beginning of the work. Only the finished part is checked in the course of pressworking and if any defects are detected, the previous operations are checked. In the second case, the preforms are checked in all operations to prevent rejects at the final stage of the process.

When a defective part is detected, the inspector prohibits further work and jointly with the foreman and worker traces the cause of it. Pressworking is resumed only after the cause has been eliminated.

When designing a pressworking process, the parameters to be checked and the measuring tools to be used are indicated in the process chart. To accept intricate parts, use is made of various appliances. Such checking appliances are made before press tools to facilitate the set-up and finishing of the latter.

2. Types of Product Inspection

Checking operations differ in the method and place of accomplishment, the time of accomplishment with respect to the production process, the scale, etc.

The inspection methods include laboratory analysis, checks on geometry and dimensions of parts, workability tests, acceptance tests, etc. *Laboratory analysis* is carried out to determine mechanical, physical, chemical and other properties of materials intended for pressworking. *Geometry checks* are used for checking shapes and dimensions of parts. External inspection of a material or part with a naked eye or with simple optical instruments serves for estimating the general condition of a material and its surface finish.

If the data of the laboratory analysis are insufficient for determining suitability of a material for a particular treatment, *workability tests* are carried out. These include drawing tests, bending tests, etc.

Depending on the time of accomplishment, there are preliminary, intermediate and final checking operations. Preliminary inspection is aimed at checking the quality of materials or preforms before treatment, for instance, mechanical and workability tests of a material intended for pressworking. Intermediate inspection is accomplished after one or several process operations. Their purpose is to exclude spoiled preforms from further treatment. The final checking operations are used to check finished parts before sending them to another shop or a depot.

As regards the *place of accomplishment*, the stationary and moving checking operations are distinguished. The former are carried out at stationary inspection points, while the latter immediately at the working stations.

By their *scale*, the checking operations are divided into complete ones where all the parts are subjected to inspection and random operations when only separate parts of the lot are checked. In pressworking the ready products usually undergo random inspection (2 to 5 per cent of the lot) and only vital parts are liable to complete quality control.

As regards the form, there are routine preventive, patrol and statistical inspection. The *routine preventive inspection* is used, for example, for checking the first stampings after mounting a new press tool. It involves checks of materials, tools, process conditions and workpieces. *Patrol inspection* is carried out by a QCD inspector periodically at the working stations for which he is responsible and consists in checking several last workpieces. *Statistical inspection* resides in periodical random checks of workpieces. It is aimed at detecting deviations from normal production conditions, thus preventing reject.

The most common method for quality control of stampings is external inspection for cracks, scores, wrinkles and other defects visible with a naked eye, and also check of dimensions with the aid of various measuring tools and instruments (see Chapter IV).

To control chemical composition of metals, quality of heat treatment and surface and to detect internal defects, use is made of *chemical* and *metallographic analyses*, fluoroscopic, X-ray ultrasonic and other flaw detection methods.

Chemical analysis determines the contents of various elements in the metal being analyzed and is based on different chemical reactions.

Metallographic analysis is intended to check the macro- and microstructures, the depth and quality of heat treatment. It is carried out on microsections, which are cut from the part to be analyzed, ground, polished and then etched with 4 per cent solution of nitric acid in ethyl alcohol. The microsections are observed with a microscope, and the macrosections, with a naked eye.

To detect fine haircracks invisible for a naked eye, in use are magnetic and fluoroscopic methods. In the first case, the workpiece is magnetized and then iron powder is applied to its surface; the contours of cracks or pits become clearly defined and visible with a naked eye.

In *fluoroscopic flaw detection* the part is treated in a mineral oil solution or in kerosene. After washing and drying the part is dusted over with magnesia powder. If it is observed in ultraviolet light, cracks and pits luminesce bright white.

X-ray and *ultrasonic methods* are intended to trace internal defects (exfoliations, voids, pits, etc.). The part is X-rayed to obtain a radiograph in which dark spots or stripes indicate internal defects.

Ultrasonic flaw detection is based on the ability of ultrasonic waves to echo from the surface separating different media. Short ultrasonic pulses are fed into the metal and the echo pulses are converted into electric pulses. The pulses are amplified and can be observed on the screen of an oscilloscope. A flaw is indicated by a spike.

The magnetic, fluoroscopic, X-ray and ultrasonic methods outlined above are termed non-destructive inspection methods.

Stampings and forgings are also checked with the use of automatic inspection units which considerably increase the efficiency of quality control.

3. Rejects in Pressworking

Pressworking rejects may stem from defects of the source material; inadequate mechanical properties of the source material, thickness, workability or surface finish; low adaptability of the part to pressworking; improper design or operation of press tools; incorrect or violated process; negligent shipment and storage of preforms and parts, etc.

Low plasticity of the material, distortions of structure or grains, non-uniform thickness, internal defects (cracks, spill) may cause *rupture* and *breakage* of workpieces.

The presence of a yield elongation zone on the metal strengthening curve may result in crippling in drawing, and hence in slipping streaks or roughness on the metal surface.

Wall thickness difference, *folds*, *burrs*, *underfill*, *ruptures* and other defects may stem from improper mounting and set-up of press tools.

Another cause of rejects is violation of the adopted production process, i.e. incorrect sequence of operations or pressworking conditions, missing of some operations (say intermediate annealing), using of blanks of wrong size, negligent securing of blanks. To prevent such rejects the workers and foremans should strictly follow the adopted production process.

Large stampings are often rejected because of *warpage*, *dents*, *nicks*, *scratches*, etc. Such defects arise from careless work, improper shipment and storage of parts.

Latent flaws are particularly dangerous. They can be revealed only by X-ray, ultrasonic and some other methods or by testing the part.

If a defect can be rectified (reclaimable reject), the workpieces are forwarded for reworking, the unreclaimable parts are remolten.

Characteristic flaws of cold die forging are external and internal cracks, scalping, tear-outs and crippling (Fig. 183).

Internal cracks appear in extrusion or drawing when the die taper angle is not selected properly or if metal plasticity is too low. Such cracks (Fig. 183*a*) cause destruction of bolts at tightening.

Lateral cracks (Fig. 183*b*) are found on parts upset on multi-strike automatic machines; these stem from the defects of a source material (haircracks, slag and other non-metallic inclusions, etc.) and from inadequate design of the process or the upsetting tool.

Shrinkage cavities and *scalping* (Fig. 183*c*, *d*) occur in direct drawing at an improperly selected degree of deformation or impermissible taper angles of the die. The defects can be remedied by changing the tool geometry or sequence of steps.

Longitudinal cracks usually result from a poor surface finish of the material. Rolling and drawing defects, haircracks or scratches lead to cracks extending parallel to the direction of upsetting (Fig. 183*e*).

If haircracks have not destroyed the part during upsetting, longitudinal breakage of the stem may occur at thread rolling (Fig. 183*f*), or the thread may swell (fall beyond the specified dimensions without any visible defects), which is also a cause for rejection.

Rejects detected by the QCD inspector are scrutinized and analyzed to find out the persons responsible for them and elaborate pre-

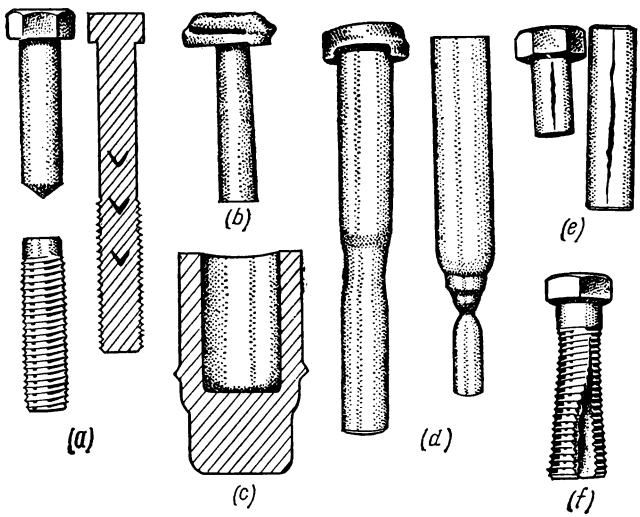


Fig. 183. Defects in cold die forging (*a*) bolt destruction (left) and location of internal cracks (right); (*b*) lateral cracks; (*c*) scalping; (*d*) shrinkage cavities on the rod at low reduction (left) and high reduction (right); (*e*) longitudinal cracks; (*f*) longitudinal rupture of the rod at thread rolling owing to haircrack in material

ventive measures. The statistics and analysis of rejects are performed with the use of special reject classifiers. The rejects are classified into types, causes and responsibility according to respective codes.

The inspector who traces rejects compiles a reject statement which should contain the data on the checked part, description of defects, their cause and the name of person to blame. The unreclaimable rejects are marked with paint, special stamp, etc.

Review Question

1. Describe the structure of a plant quality control department.
2. What types of quality control do you know?
3. How are rejects accounted for?

Chapter XV

FUNDAMENTALS OF HOT FORGING

1. Hot Forging Process

Hot forging is used when cold deforming is impossible. When a metal is heated its ductility drastically rises while the resistance to deformation decreases considerably. Hot forging is used to work steel, non-ferrous metals and alloys. Pitmans, stepped shafts, gears, various levers and other parts are made by forging.

The hot forging process comprises preparatory, forming and final operations.

The source materials for hot forging are rolled and formed bars, ingots, cast shaped blanks. The source material is cut into blanks of the specified size at the blank preparation shop.

The source material is cut by different methods such as shears cutting, press tool cutting, cold-short breaking, torch cutting, machine cutting, grinding wheel cutting, electrochemical rotary cathode cutting, spark cutting, plasma cutting, etc.

Shears and crank press cuttings are used most frequently today.

Small-diameter stock is cut cold. The bars from 80 to 150 mm in diameter are heated to about 400°C before cutting on shears, which ensures a high finish cut.

Large-diameter bars are severed into blanks by breaking them on crank or hydraulic presses. The bar is notched at the points of breakage with saws or torches.

Torch cutting is used mainly with large-diameter rolled stock. This method is not efficient, besides a part of metal burns out.

Machine cutting is performed by circular and band saws or on lathes with a cutting-off tool. The blanks have smooth and even faces; however, the efficiency of this method is low if compared with shearing. Grinding wheels are used for cutting hard and strong metals and alloys.

Other methods of cutting are used more rarely.

The blanks are heated in flame or electric furnaces or in induction heaters. Sometimes molten salts and glass are employed for the purpose.

To obtain quality forgings, heating conditions established for each metal should be strictly observed. Numerous tests have been carried out to find the temperature ranges for hot forging of different materials, i.e. the initial and final temperatures of forging. For instance, the recommended range for steel 10 is from 1 280° to 750°C, for steel IIIX15, from 1 120° to 850°C, etc.

Heated blanks are forged on hammers, crank presses, screw presses, horizontal forging machines and other equipment.

Depending on the equipment used, the hot forging tools are divided into hammer, press, upsetting (for horizontal forging machines and hot upsetting automatic machines) tools and forging rolls. The blank takes the shape of the tool working cavity termed an impression. Plain forgings are made in single-impression tools, intricate, in multi-impression ones (Fig. 184*a* to *e*). The impressions may be roughing

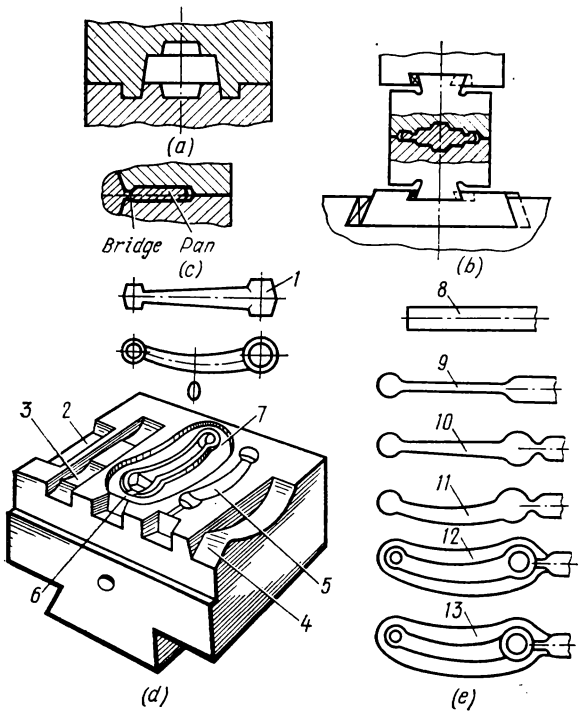


Fig. 184. Die forging tools

(*a*) closed; (*b*) open single-impression; (*c*) flash gutter; (*d*) lower half of an open multi-impression tool; (*e*) forging steps; *1*—forging; roughing impressions; *2* — fullering; *3* — edging; *4* — bender; forging impressions; *5*—blocking; *6*—finish; *7*—flash gutter; *8*—blank; *9*—fullering; *10*—edging; *11*—bending; *12*—blocking; *13*—finishing

and forging. The roughing impressions (fuller, edger, bender, etc.) redistribute the blank metal along its axis. The forging impressions may be blocking and finishing. The finishing impression is usually surrounded with a flash gutter. The excessive metal flows to the gutter during forging thus forming a flash.

The tools for forging with flash are called open, those for flashless forging, closed.

The gap through which the metal flows into the flash pan (gutter) is narrow (Fig. 184*c*). It impedes the metal flow. Besides, the metal cools more rapidly in this zone and resists the metal flow, making it fill all the elements of the impression.

When making a forging drawing, the designer refers to the drawing of finished part *1* (Fig. 185). Then he selects the required direction of

metal fibres and the parting plane. This plane divides the forging into two parts formed in the upper and lower tools respectively. Next, the designer calculates allowance *2* and tolerance *3* (Fig. 185).

Allowance is a layer of metal to be further removed by machining. The metal surface defects should be in the allowance. The higher the forging quality, the smaller the allowance.

The tolerable deviation of the forging from the specified dimensions is called *tolerance*.

To simplify the forging shape, facilitate the process and allow withdrawal of the forged part from the tool, provision is made for rounding radii, drafts, bridges, etc., which adds some metal called *additional* (or *forging*) *allowance*.

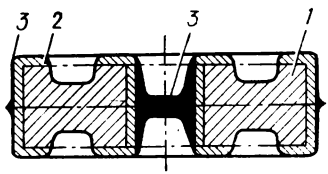


Fig. 185. Drawing of a forging

The forgings are subjected to final and finishing operations. These include: flash trimming, hole piercing, heat treatment, descaling, straightening and sizing.

Flash trimming and hole piercing are carried out in special trimming tools on crank or hydraulic presses. Then the forgings are heat treated to toughen the metal. Heat treatment may include normalizing, annealing, hardening and tempering.

The forgings are descaled by shot-blasting, tumbling or pickling.

To eliminate warpage, hot or cold straightening is used; geometrical accuracy is improved by sizing. The sizing differs from straightening in that the former involves changes in the forging dimensions, while the latter eliminates warpage without such changes.

After the straightening and sizing operations are completed, the forging is checked for geometrical accuracy, structure and mechanical properties of its metal. The forged parts are transferred for further machining only after the checks for compliance with the specifications and drawings.

2. Drop Forging

The *steam-air hammers* comprise the following main components: a bed, an anvil, a cylinder, drops, and lubrication and control systems. The drops of a hammer include a ram, a rod, a piston, and an upper tool.

These hammers make the backbone of the hot forging equipment. They are actuated by steam or compressed air. Steam is delivered to the hammer from boilers or steam power plants, and compressed air, from compressors. Steam or compressed air gets into the cylinder via special pipelines.

There are single- and double-action steam-air presses. In the single action presses, steam or compressed air acts on the piston and hence on the drops linked with it, only to lift them to the top position. The blows are delivered by the falling drops. Such hammers are rarely used at present.

In double-action steam-air hammers, steam or compressed air not only lifts the drops upward but is also fed to the upper part of cylin-

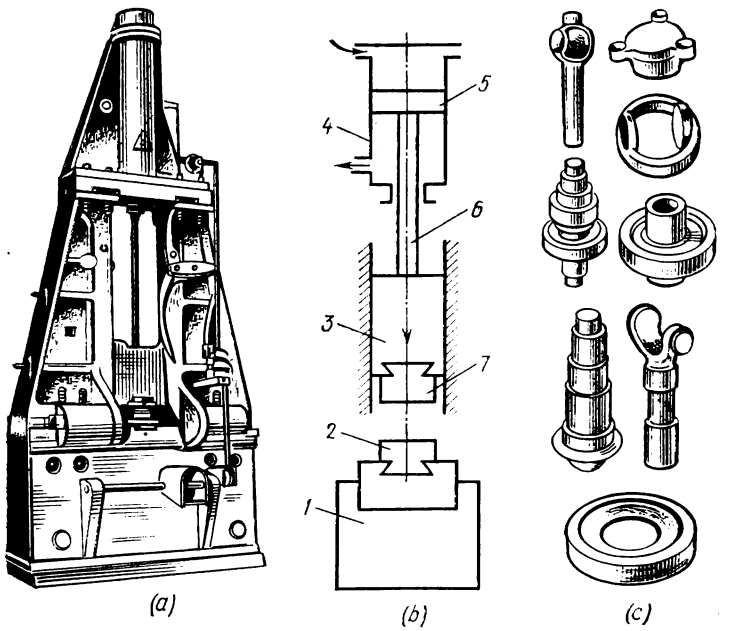


Fig. 186. Double action steam-air hammer M211
(*a*) general view; (*b*) operating diagram; (*c*) forgings; *1*—anvil block; *2*—tool lower part; *3*—ram; *4*—working cylinder; *5*—piston; *6*—rod; *7*—tool upper part

der *4* (Fig. 186*a*, *b*, *c*) to impart additional impulse to the drops. This considerably increases the blow energy. Such hammers can be used in the helver, single- and automatic-blow modes. The hammer is controlled with the aid of a pedal.

The steam-air hammers are manufactured with a drop mass of from 630 to 25 000 kg. The drop mass of the hammer indicates its power.

In addition to steam-air hammers, *machine hammers* are used for drop forging. These include board drop, belt drop and chain drop hammers. The ram is lifted owing to friction between the rotating rolls and the board, or by a belt or with the aid of a special lifting

mechanism wherein the belt and chain serve only for connecting the ram with the lifter. These hammers are seldom used in modern forging shops.

Rapid-action counterblow hammers are intended to make intricate parts from hard-to-deform metals and alloys, including refractory and high-melting ones, and from construction and alloyed steels. The forgings made on these hammers require little machining.

Open tool drop forging is a widely-used and universal method of metal working. Forgings from 0.1 kg to several hundred kilograms can be made by this method.

Closed tool drop forging is gaining wide application owing to the absence of flash and simplification of the technology.

3. Hot Forging on Crank Presses

Hot forging crank presses (Fig. 187*a*, *b*) are manufactured for a rated force of from 630 to 8 000 tf (6 300-80 000 kN) and are used in the mass and large-batch production. The use of these presses instead of hammers considerably improves labour conditions owing to elimination of vibration, reduction of noise and possibility of large-scale automation.

The tools for hot forging crank presses consist of a block and a set of impression inserts. Various parts are forged by changing the impression inserts in the block. The tools are equipped with knock-outs for better accuracy.

The productivity of the hot forging crank presses and the quality of forgings are well above those of drop hammers.

However, the hot forging crank presses cannot be used for such operations as fullering and edging because of the constant stroke of the slide.

To compensate for this shortcoming, a wide use is made of forging rolls-and-press installations. The forging rolls perform operations for preliminary distribution of the blank metal. Besides, die rolled stock blanks are employed.

The main assemblies of a hot forging crank press are: a frame, slide, clutch, brake, bed, drive, lubrication and control systems. Torque from electric motor *4* (see Fig. 187) is transmitted through pulley *3* and V-belt transmission to flywheel *2* provided with brake *1*. The flywheel is mounted on driving shaft *15*. The opposite end of the shaft carries gear *9* which meshes with gear *7* freely mounted on crankshaft *6*. The shaft will rotate only when friction clutch *8* is engaged. The crankshaft imparts motion via pitman *14* to slide *13* which carries the upper tool. The lower tool is secured by wedge (dovetail joint) *10* to shoe *12* of bed *11*. Brake *5* serves to stop the crankshaft when the slide is in the top position.

The press is equipped with upper and lower knock-outs.

The blanks intended for being worked on the hot forging crank presses should be descaled or heated in non-oxidation atmosphere.

4. Forging on Hydraulic Presses, Horizontal Forging Machines and Special-Purpose Machines

Hydraulic presses are used for hot forging of large parts, working low-ductility alloys and for performing other operations where a long

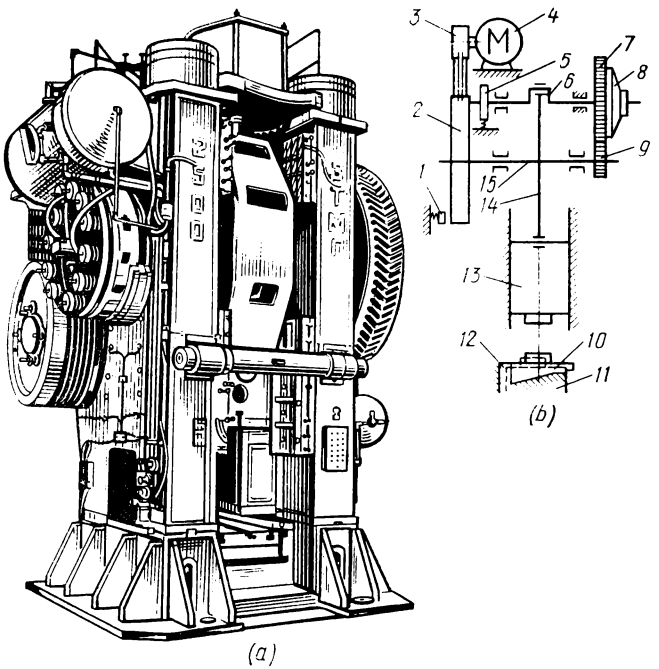


Fig. 187. Hot forging crank press K8544 with a rated force of 2500 tf (*a*) general view; (*b*) mechanical diagram

stroke is needed. The hydraulic presses have low productivity and are used for hot forging only when hammers or hot forging crank presses cannot be employed.

Hot forging hydraulic presses with a rated force of from 1 000 to 75 000 tf are manufactured in the USSR.

Horizontal forging machines are widely used for making various parts from steel and non-ferrous metals, such as valves, automobile half-axles, gears, rings, etc. The horizontal forging machine is a crank press with a horizontal slide. They come with a rated force of from 100 to 3 150 tf.

Such machines can be used for multi-step high-speed (up to 100 strokes per minute) forging from bars. The horizontal forging machines with the vertical parting plane of the die (Fig. 188*a*, *b*) have found the widest application. A plurality of devices for automating the horizontal forging machines have been implemented in the industry.

Automatic hot forging machines are gaining recognition. These are employed for mass production of bolts, nuts, stem parts with

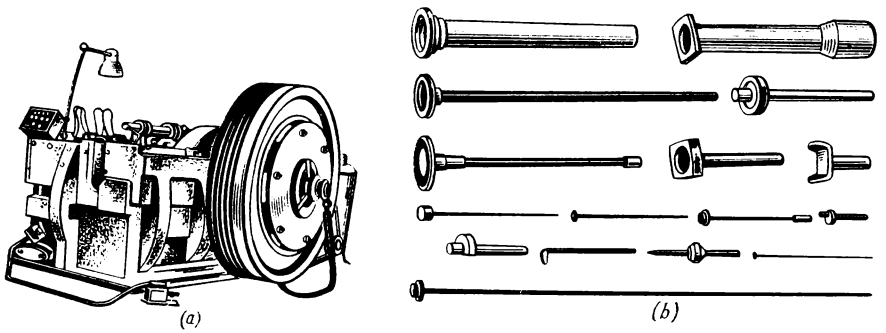


Fig. 188. General view (*a*) of horizontal forging machine ГКМ В111 and examples of forgings (*b*)

head, cross-pieces, etc. The machines are turned out complete with heaters and automatic stock feeders. As regards the productivity, such an installation takes the place of up to ten horizontal forging machines in the production of similar workpieces.

Figure 189*a* shows the steps for forging a cross-piece from bar on a *three-station hot upsetting machine*. At the first station, the blank severed from a heated bar is subjected to open upsetting between flat block heads. The upset blank is transferred by a grip feed to the second station for being formed in an open tool. The flash resulting from the second step is trimmed at the third station. The capacity of the automatic machines for making such parts is from 80 to 85 pieces per minute.

An example of the process for flashless forging of a gear blank at a four-station automatic machine is shown in Fig. 189*b*.

On the electric upsetting machines the metal is heated directly in the forming zone. Such machines ensure production of long stem-like parts with a considerable thickening (up to 20-30 diameters of the initial blank) at the ends and middle of the article.

Forging rolls (Fig. 190*a*) are used for making variable cross section forgings from heated blanks. The rolling process (*I-II*) resides in deforming the blank by rotating sector dies *2* (Fig. 190*b*) secured on rolls *1*. When the dies are set to the idle position, the blank is fed

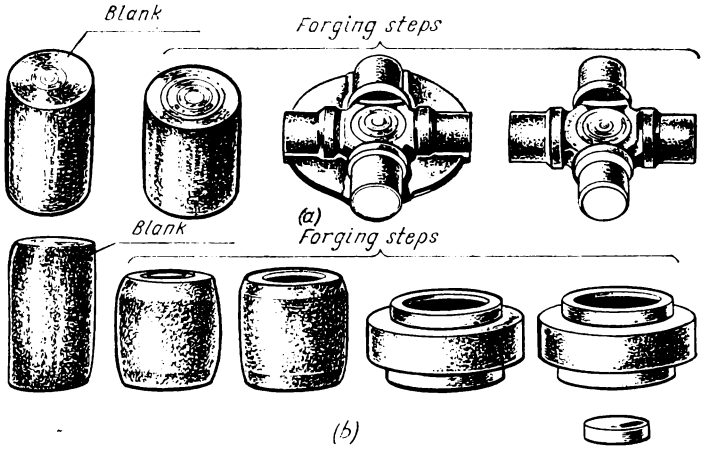


Fig. 189. Examples of hot forging steps with (*a*) and without (*b*) flash on multi-station automatic machines

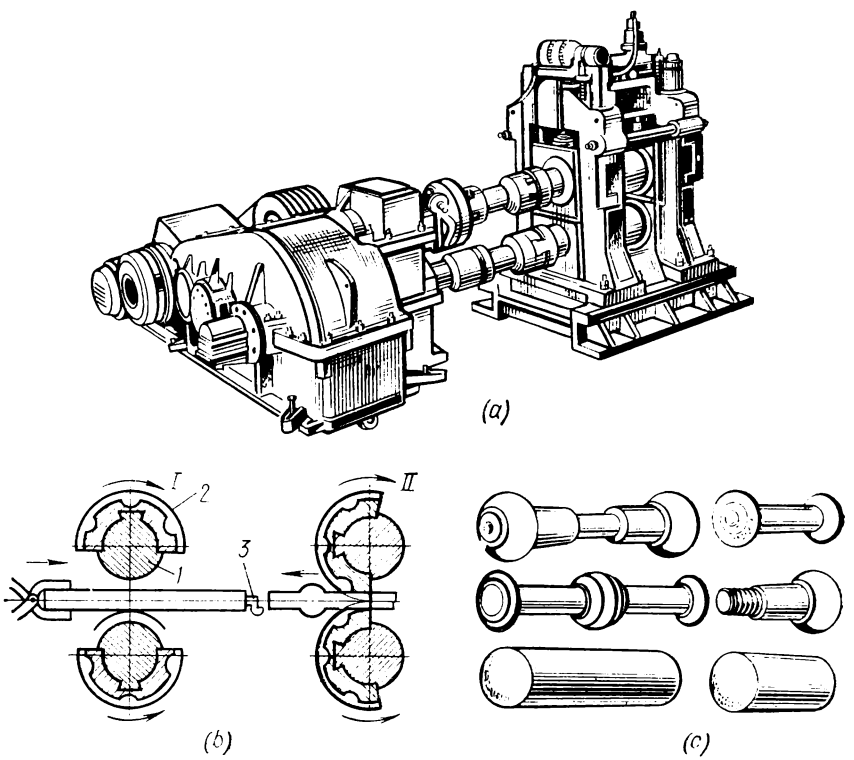


Fig. 190. General view (*a*) of forging rolls C1237, operating diagram (*b*) and forgings produced (*c*)

to thrust against stop *3*. Reduction is synchronized with displacement of the blank. Intricate cross section forgings (Fig. 190*c*) are formed by passing several times through dies of different shapes.

Some forging rolls are mounted on casters for easy displacement from one working station to another, which may be necessary in the case of small-batch production.

Rotary forging machines (Fig. 191*a*, *b*) are intended for forging bars and beading pipes. The machine operates on the principle of

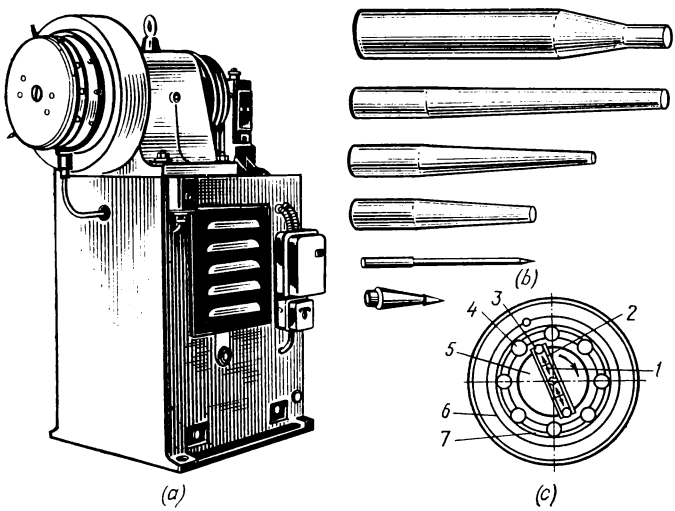


Fig. 191. General view (*a*) of rotary forging machine B2118, forgings produced (*b*) and operating diagram (*c*)

applying multiple impacts to the blank with the aid of strikers *1* (Fig. 191*c*). The reduction (forging) mechanism includes rotating spindle *5* and stationary holder *6* with cage *7*. Spindle *5* has radial slots for slides *2* with strikers *1*. Rollers *3* are mounted on the slides. When the spindle rotates the slides with strikers are moved by the centrifugal force away from the centre. The slides riding with rollers *3* on the rollers of cage *4* displace towards the centre while strikers *1* apply impacts to the blank.

In some types of the rotary forging machines, the spindle is stationary while the holder rotates. This provides for making articles which are non-round in cross section.

In addition to the above equipment, hot forging can be performed on radial forging machines, friction presses, horizontal bending machines, installations using explosion energy, etc.

Review Questions

1. Describe the main methods of making blanks for hot forging.
2. What is the hot forging temperature range?
3. What is the difference between open and closed press tools?
4. What equipment is used for hot forging?
5. Outline a hot forging process.

Chapter XVI

FUNDAMENTALS OF STANDARDIZATION AND PRODUCT QUALITY

1. Basic Terms and Definitions

A standard part or an article is a part or an article manufactured in compliance with particular unified requirements for the shape, dimensions, surface finish, etc. Such parts must be interchangeable and meet modern quality requirements. For instance, nuts and bolts of the same standard size should fit the corresponding threads irrespective of the manufacturer; any bulbs must fit the corresponding bulb-holders, electric appliance plugs must enter into receptacles, etc. Besides, it is necessary to set up uniform names for operations, parts, units of measurements and other characteristics. To satisfy the above conditions, a particular code is required. Such a code should define the basic terms and notions and also the requirements for products the infringement of which is impermissible. The part of such a code is played by standards.

The meaning of the terms "standardization" and "standard" was changing with progress in science and technology.

In 1962, the International Organization for Standardization adopted a definition of the standardization as an act of establishing and using rules intended to organize the activities in a definite field for the benefit and with the participation of all the interested parties, in particular, for ensuring general optimum economy with the operating conditions and labour safety being observed.

A standard is a result of concrete work for standardizing, approved by a competent body. It may be a document setting up a number of requirements to be met; a basic unit or a physical constant (e.g., second, absolute zero, etc.); an object for physical comparison.

The standardization is of paramount importance for machine building. It ensures a drastic decrease in the number of processes for manufacturing similar parts, design of typical production processes, setting up of general systems of technical documents and cutting of their number. Standardization is based on the achievements in sci-

ence and technology and on the deep analysis of prior art. Standards should not only define the present state of the art but also forecast its progress.

The state standards being a quintessence of the advanced experience and recent achievements of science and technology, correlate them with the national economy prospects, promote their development, improve product quality and widen international trade and cooperation.

Depending on the requirements contained in them, the standards are divided into 13 types: (1) standards for specifications; (2) standards for parameters (dimensions); (3) standards for types and basic parameters (dimensions); (4) standards for grades; (5) standards for assortment; (6) standards for designs and dimensions; (7) standards for technical requirements; (8) standards for acceptance procedures; (9) standards for test procedures; (10) standards for marking, packing, shipment and storage; (11) standards for measuring instrument testing methods and means; (12) standards for operation and maintenance; (13) standards for typical production processes.

The main methods of standardization are unification and typification. *Unification* is a rational reduction of the number of standard sizes and types of articles having similar application. In machine building, major attention is paid to design unification, i.e. unification of the embodiments of similar articles. The unification is of great importance for the tool parts of presses and forging machines, where up to 90 per cent of structural components can be unified. The principal object of unification in machine building is to create the maximum number of machines, mechanisms, automation devices, etc. from a limited number of unified assemblies and parts with the addition of some special units.

Typification is the development of typical design and engineering solutions, or typical production processes. The typification considerably cuts the time and costs of design and elaboration of the production processes for similar-type parts with minor differences.

2. Measurements and Units of Measurement

Measurement is ascertaining the quantity, mass, extent or degree with the use of special instruments. To make the measurement results universally apparent, the units of measurement, measuring methods and means ensuring the required accuracy should be legalized. The science dealing with these problems is called metrology.

Billions of various measurements are taken daily. In the USSR the cost of measuring equipment in machine building exceeds 15 per cent of the production equipment cost.

To ensure unity and trustworthiness of measurements on a national scale, the State Metrological Service is set up in the USSR. It in-

cludes research institutes, regional metrology and standardization centres, national inspection laboratories supervising the implementation and observance of standards and condition of measuring equipment.

The State Metrological Service establishes physical units allowed for use, elaborates the national reference systems and standard checkout procedures, develops reference measuring means, standard methods and means for measurements and inspection, supervises instrument making and maintenance, etc.

All the measuring means both home-made and imported, are subjected to compulsory state tests. Prior to starting their series production or releasing for use, these means are tested for compliance with the specified norms and latest developments in the instrument making field. Two types of state tests are established: acceptance tests for the prototypes of new measuring means and check tests for batch-produced measuring means.

Supervision over the condition and proper use of measuring instruments gains great importance for ensuring the unity of measurements in the national economy. Regular checks of measuring instruments guarantee the trustworthiness of measurements.

3. International System of Units

The progress of science and technology required a tremendous number of various measurements. To provide common notions about the quantities and objects being measured it was necessary to introduce units of measurement. By 1950's several systems of physical units were in use in different countries. The inconveniences involved in conversion of units from one system to another demanded creation of a general system of physical units.

Such a system was elaborated and approved in 1960 by the General Conference on Weights and Measures. It was named the International System of Units (SI). The SI establishes seven basic units: metre (m) for length; kilogram (kg) for mass; second (s) for time; Kelvin (K) for temperature; ampere (A) for current; candela (cd) for candle power; mole for quantity of a substance. From these basic units and two additional ones (radian and steradian) for measuring angles, units are derived for measuring various physical quantities (force, pressure, power, voltage, etc.).

The introduction of the SI is of paramount importance. The system covers all branches of science and technology, simplifies equations and formulae by eliminating the need for different conversion factors, gives general units for all kinds of measurements (e.g. pascal takes the place of a plurality of units for measuring pressure: atmosphere, mm Hg, mm H_2O, bar, pieza, dyn/cm^2, etc.).

4. Standardization and Product Quality

The task of improving product quality and quality control is very urgent today. The term product quality implies a combination of properties and indices which make an article capable of meeting particular requirements and fit for task used for its designated purpose.

A system of indices and methods for determining same have been elaborated to estimate the quality of various products. The most significant indices of quality, reliability and longevity are set forth in relevant standards.

Reliability is the ability of a machine to perform the designed functions with the operation characteristics being preserved within the required period of time. *Longevity* is the ability of a machine to remain operable up to its final condition with required intervals for maintenance and repair. Final condition is a condition after which the machine cannot be operated. To estimate the longevity of a machine, use is made of such notions as service life which is the amount of machine operation in terms of hours, m^3, hectars, articles produced, etc., and lifetime which is a calendar period of operation up to the final condition.

Review Questions

1. What does the term "standard" mean?
2. What was the cause for introduction of international standards?

Chapter XVII

LABOUR PROTECTION AND FIRE PRECAUTIONS

1. Fundamentals of Labour Protection

Labour protection is a complex of measures intended to prevent traumatic injuries and occupational diseases. Traumas and occupational diseases result from organizational or design faults, violation of the established manufacturing process, ignorance or infringement of safety regulations.

Labour protection measures include providing machines and rooms with special means and devices which ensure safe and harmless work and elaborating safety rules to be observed by the personnel. All the workers should know well and infallibly follow safety rules and sanitary norms.

Pressworking relates to hazardous processes, therefore particular attention should be paid to press shop labour safety.

The management of the enterprise and shop should take all necessary technical and organizational measures to ensure adequate safety and sanitation, demand strict observance of labour protection and safety rules.

A new worker is instructed in safety practices and should study plant safety regulations and local codes (pertaining to his particular job). Next, the foreman should familiarize the newcomer with the rules of operating the equipment and handling facilities, working station keeping, demonstrate pressworking safe techniques. Besides, the foreman periodically instructs the workers in safety precautions and supervises their observance.

The general safety precautions require that each worker should begin his work with checking the operability of presses and tools and running them idle. When repairing, cleaning, lubricating the press, the DO NOT CUT IN—REPAIR warning placards should be hung near the starting devices. Each worker should be on guard not to be in the way of moving transport and handling facilities, never stay under a lifted load, enter inside the protection enclosure or work without protective shields, touch the machines and electrical devices attended by him, etc. It is prohibited to enter the rooms with the AUTHORIZED PERSONNEL ONLY inscriptions.

Care should be also exercised when walking over the territory of the plant. The hazardous areas of the plant territory (construction sites, handling areas, etc.) should be fenced. To prevent accidents, sound and light signalling, warning inscriptions (e.g. NO THROUGHFARE), illumination of the territory during twilight and night hours are extensively used.

2. Prevention of Accidents in Pressworking Shops

Industrial accidents include all cases of injury to a worker caused by harmful foreign or external influences and events arising in the course of production. They can be mechanical (blows, cuts, breaks, wounds), electrical (shocks, burns), thermal (burns), chemical (burns), acoustic (noise contusions), visual (short- and long-time blinding), etc.

Any trauma should be reported and every accident recorded according to relevant legislation and regulations.

The causes of accidents are divided into production (the use of hazardous methods of work infringing the safety regulations; inadequate personal protection means, shortage of or failure to use such means; poor layout and upkeep of working stations; lack of instruction in safety precautions or deficient supervision over their observance, etc.), technological (obsolete production processes and equipment, defective tools and fixtures, safety guards and protective devices, etc.) and sanitary (poor lighting, adverse atmospheric conditions in the premises, etc.).

The prevention of accidents in production shops involves engineering, organizational and sanitary measures.

Engineering measures include the use of machinery that is safe to operate, adjust and repair; the mechanization and automation of heavy, labour-consuming and hazardous processes; the transfer of working manipulations from hazardous zones to safe areas; the arrangement of safety guards and enclosures around moving, current-carrying and other dangerous parts, units, machines and devices; preliminary testing of equipment, provision of proper insulation, etc.

Organizational measures include proper layout of equipment and correct traffic routing in a shop; proper layout and good upkeep of working stations; systematic training of workers in safety precautions and in safe methods of work with check up of their knowledge; prohibition of working with faulty equipment or defective tools, prohibition of dangerous working methods; prohibition of start-up of new equipment without the approval of the authorized personnel; provision of personal protection means and check of their use; issuing of leaflets or manuals on safety precautions to each worker, etc.

Sanitary measures include the provision of good ventilation, lighting, etc.

Typical industrial injuries in pressworking shops are pricks and cuts and minor traumas to the fingers and hands, arms up to the elbow, and, sometimes, to the legs and feet caused by sharp corners, edges or burrs on blanks, preforms, finished parts and scrap when they are placed in, removed from the tool, or carried, etc. Injuries can be largely reduced through mechanization and automation of pressworking operations. To prevent injuries during manual feed and withdrawal of small parts, use should be made of tweezers or tongs, while the entrapped scrap should be removed with a hook. The worker handling middle-size and large components should always wear gloves and never touch the sharp corners and edges of the blanks, preforms, etc.

Many accidents in pressworking shops are caused by the falling of blanks, hand tools, press tools, etc. For this reason, one should be very careful when carrying or moving parts and tools. Uneven floors, junked working stations, blocked aisles are other sources of injuries, therefore the working stations should be tidy and roomy. Loads handled by cranes must be securely attached to the hooks and should never be swung over the heads of people. Standing under the lifted load is prohibited.

The press tools are made closed if possible (see Chapter VII) and the presses are equipped with safety devices. These include sweep guards, two-button (two-hand) switches (Fig. 192), interlocking guards which immediately stop the press if a hand gets into the working zone.

Two-button switching is used to keep the hands off the dangerous zone during start of the press. The press can be cut in only by simultaneously pushing two buttons spaced at least 300 mm apart to preclude one-hand switching. The photocell protection systems are employed for instantaneous stoppage of the press when the hand gets into the dangerous zone and for prevention of press starting

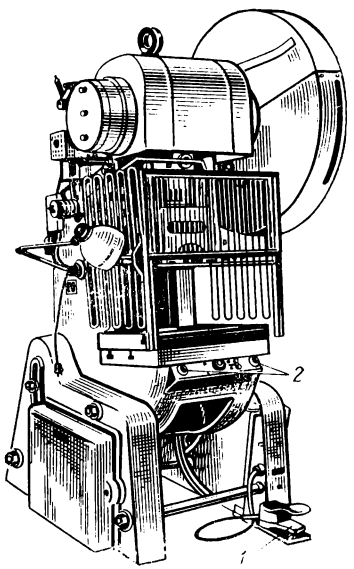


Fig. 192. Double-arm open crank press with barrier guards, a pedal and two-hand (two-button) switching and local lighting of tool area
1—cut-in pedal; *2*—two-hand push-buttons

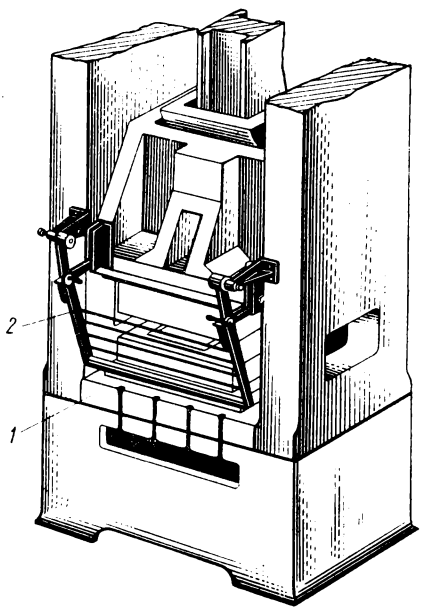


Fig. 193. Sweep guard
1—bed plate; *2*—deflecting frame

till the hands are in the working space of the press. The photocell protection system is based on interrupting a light beam passing through the working space of the press by the worker's hand, which changes photoelectric current and activates a relay. The press stops and cannot be re-started before the obstruction to the light beam is removed.

The *sweep guard* (Fig. 193) is so designed that when the slide moves down the grating turns towards the operator and makes him back away and withdraw his hands from the dangerous area.

Vertical and horizontal pendulum-type sweep guards (Fig. 194) swing in front of the press when the slide descends and push the

operator's hands away from the dangerous zone. To soften the blow of the pendulum, it is padded with a ring of sponge rubber.

Accidents are often caused by the press operator failing to observe the operating and safety rules. Small parts should always be handled with tweezers or tongs, a press with defective tools should never be operated, the worker should not distract for talks. All operators should strictly keep to the rules of operating their machines and observe the safety code.

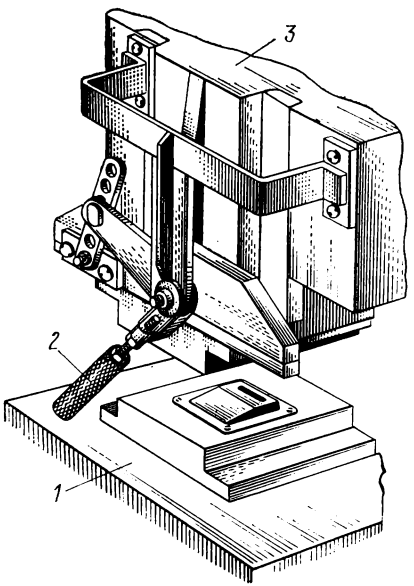


Fig. 194. Vertical pendulum-type guard
1—press bed; *2*—guard; *3*—slide

To avoid electric shocks and burns, operators are not allowed to adjust the electrical circuits or to mend them. All electrical systems and the press should be earthed.

3. Industrial Sanitary

Industrial sanitary involves measures for proper arrangement and upkeeping of industrial enterprises and equipment as regards sanitary norms (good ventilation and lighting, proper layout of the equipment, etc.) and is aimed at creating healthy and favourable working conditions for preventing the adverse effect of occupational hazards.

Occupational hazards are certain factors in the production process or in the working conditions that are detrimental to the health or efficiency of workers. The occupational hazards include unfavourable microclimate in working premises, noise and vibration, poor lighting, invisible radiation, industrial dust and toxic agents, occupational infections and bad working schedule.

Bad working schedule and wrong posture during the work (Fig. 195*a*, *b*) lead to excessive strain or fatigue in certain muscles and organs which can bring on occupational diseases. Therefore, the press controls that are most frequently used should be arranged in the optimum working zone (Fig. 195*c*).

For effective prevention of occupational diseases, pressworking shops should be provided with adequate ventilating equipment and lighting facilities ensuring proper illumination of both the working stations and the shop. Production equipment and the premises should

be painted in soft light colours. Noise reduction measures should be systematically taken (installation of sound-absorbing structures, isolating noisy processes in separate rooms). Press operators making small parts should be provided with special seats convenient for their work, while those engaged on large parts should have seats for short breaks.

Workers who have to continually watch the operation of automatic lines or presses should be allowed short breaks at regular intervals. Women and adolescents must never be permitted to lift

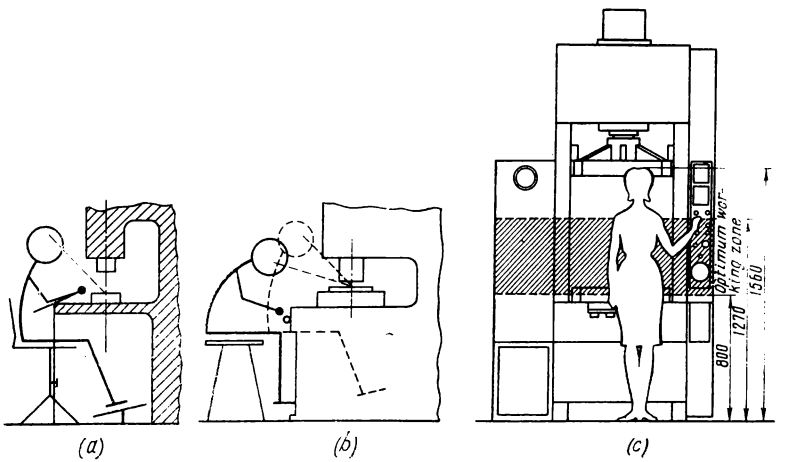


Fig. 195. Press operator's posture when seated
(*a*) correct; (*b*) wrong; (c) optimum arrangement of press controls

weights exceeding the established limits. Washing facilities (showers, basins) and detergents must be provided so that workers can clean up for meal breaks and after work; this is especially important when pressing is accomplished with the use of composite lubricants. Physical exercises should be arranged to relieve muscular strain.

4. First Aid

First aid is the simplest immediate measures taken when a worker is injured or suddenly falls ill. It is offered before the arrival of a doctor or taking the victim to the medical room.

Traumas and attacks of some illnesses are unexpected and sometimes even a several-minute delay in rendering help may bring about rapid spread of illness or injury effect. Therefore, every worker should know how to render first aid and every shop must always have first-aid kits.

Those rendering first aid should first of all remove the cause of the accident: shut off gas in case of poisoning or cut out power in case of electric shock, withdraw the dropped load, etc. Then the victim is evacuated from the dangerous zone, rendered first aid (to recover consciousness, stop bleeding) and a doctor is immediately called.

In case of electric shocks, the mains should be de-energized by cutting out a knife switch or severing the leads. The rescuer must be well insulated when severing the leads and should wear rubber gloves and dry clothing. Next, artificial respiration should be applied to the victim.

If a worker is wounded, bleeding must be stopped and a bandage applied to prevent infection before arrival of a doctor.

5. Fire Protection

Careless handling of flames, faulty electrical systems and self-ignition of flammable materials (cleaning rags and waste, scrap, etc.) are the main causes of fire in pressworking shops.

The antifire measures for machine building plants are divided into preventive, organizational and fire extinguishing ones.

Preventive measures include those ensuring proper siting of buildings, roads and passages, the correct layout of shops, the use of suitable building materials, and the provision of safe and fire-prevention equipment, etc.

Organizational measures are aimed at taking fire precautions at the plant and in shops and include prohibition of infringement of technological requirements or smoking at unauthorized places, regular checks of electrical devices, storage of lubricating and cleaning materials in safe places, etc.

Fire extinguishing measures include organization of plant fire teams, provision of fire-fighting water pipelines and alarm systems, fire-fighting facilities (extinguishers, sand bunkers, hitchers, crowbars, etc.), organization and training of shop fire teams (groups).

All the workers should know and strictly observe the fire prevention rules—never smoke at unauthorized places or drop burning cigarettes and matches, always cut out electrical appliances and local illumination after work or during breaks, immediately cut out overheating or sparking electric motors or other electrical apparatuses, keep lubricating and cleaning materials at specially assigned places. Oiled cleaning materials often cause fire. They should be stored in metal boxes emptied at the end of the shift. It is prohibited to keep oiled and dirty overalls in closets or cabinets.

If a fire starts, it is necessary to act quickly, promptly and without panic: inform the fire brigade at once either by using the fire alarm or over the telephone, switch off ventilation since the supply of fresh

air will spread the fire, cut off electricity, gas and compressed air sources and join in fighting the fire.

The members of a shop fire team or group should stop work immediately on fire alarm or noticing a fire, switch off energy sources and start extinguishing the fire (deploy fire-fighting facilities, extinguish flame, salvage property from the danger zone, etc.). The other workers should help them or leave the danger zone when ordered to do so.

To put out fires in buildings and structures, either water or extinguishing agents are used. Burning liquids are put out with chemical extinguishers. Water is useless since the burning substances float onto its surface and continue to burn. Fires in electrical equipment are put out with sand or by means of carbon dioxide extinguishers. Water or chemical foam do not suppress them. Moreover, water and foam conduct current and can cause serious electric shocks or burns.

Every worker should know how to call the plant fire team over the telephone, where the nearest fire alarm and extinguisher are and how to use them. All commands of the fire team members and shop management must be obeyed without delay or argument by everyone on the site.

Review Questions

1. What are the main purposes of labour protection and safety precautions?
2. What measures have to be taken to ensure safety in pressworking shops?
3. What measures must be taken to prevent occupational diseases?
4. How is first aid rendered to the victims of mechanical injury or electric shock?
5. Describe fire precautions for a pressworking shop.
6. How should you act in case of fire in the shop?

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